A model for the translation of South African economic activity into shipping container demand

Joubert van Eeden

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Supervisor: Prof Jan H Havenga
Co-Supervisor: Prof Cornelius SL Schutte

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DECLARATION

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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ABSTRACT

Quay wall container forecasts are often done by broad-stroke methods with large-scale infrastructure decisions then based on these forecasts. This **research problem** requires an investigation into more accurate long-term forecasting methods. A **mixed methods research design** was followed, combining quantitative and qualitative data, with the **primary objective** to establish design requirements for and to develop a content-based quay wall container framework. **Secondary objectives** were to also establish design requirements for quay wall modelling frameworks for transhipment and empty containers. These secondary objectives originated from exposure to literature and data from the primary research.

The **aim** of this dissertation was to redefine the importance and usefulness of content-based container forecasting techniques. This would enable **port planners** to base their container volume forecasts on economic activity, i.e. validated demand, and not on the perceived reality of historic containers or other broad indicators.

The **mixed method design** combined **literature** on container modelling techniques, demand-side and supply-side container shipping factors and the impact of port networks on quay wall container volumes. The literature showed only a few scholars venturing into the field of high granularity container forecasting methods. Those that did propose methods used mostly derivatives of traded commodities like GDP, trade, or population growth as input drivers. Many scholars referred to, but very few used container contents in their modelling, mostly due to data unavailability.

Rich **secondary datasets** received from various parties, i.e. TNPA, SARS, TFR and shipping lines, were all instrumental in understanding the relevant parameters. All datasets contributed in their own way to the development of the final set of parameters. To support this secondary data, **primary research** was conducted with freight owners, industry associations, LSP's, shipping companies, port authorities and terminal operators via **a survey and focus groups**. Feedback from survey respondents and focus groups confirmed the **user requirements** identified earlier. It also confirmed the importance of the identified requirements and the inputs that were obtained from analysing container content data.

Design requirements were consolidated from all the mixed methods research inputs. **Key parameters** to forecast full container volumes across the quay wall are:

- Spatial disaggregation to define outputs per international geographic region and per port;
- Rate of containerisation of each commodity;
- Commodity port preference;
- Physical container types;
- Weight of commodity per physical container type.

The **container modelling frameworks and modelling process** for three functional typologies, were developed based on the design requirements. The inputs, parameters, modelling process, forecasting influencers and outputs for each of the defined functional typologies were discussed separately with a confidence level for each of the aspects. The confidence levels provides an indication of the current status of the parameter values and provides guidance towards future improvement areas.

The container modelling frameworks went through a **verification and validation process**. The proposed model is expected to provide a more accurate container forecast to port infrastructure planners. Using these drivers in forecasting models will inform port planners with validated demand towards calculated decisions on initiating port container infrastructure projects at the right moment in time.

OPSOMMING

Kaaimuur houer vooruitskattings word dikwels gedoen deur breëstrook metodes met grootskaalse infrastruktuurbesluite wat dan gebaseer is op hierdie voorspellings. Hierdie navorsingsprobleem vereis 'n ondersoek na meer akkurate langtermynvoorspellingsmetodes. 'n Navorsingsontwerp met gemengde metodes is gevolg, deur kwantitatiewe en kwalitatiewe data te kombineer, met die primêre doelwit om ontwerpvereistes vir en die ontwikkeling van 'n inhoudsgebaseerde kaaimuurhouerraamwerk te vestig. Sekondêre doelwitte was om ook ontwerpvereistes vir kaaimuurmodelleringsraamwerke vir oorladings- en leë houers te vestig. Hierdie sekondêre doelwitte het natuurlik ontstaan uit blootstelling aan literatuur en data uit die primêre navorsing.

Die doel van hierdie proefskrif was om die belangrikheid en bruikbaarheid van inhoudsgebaseerde voorspellingsmetodes vir inhoud te herdefinieer. Dit sal hawebeplanners in staat stel om hul houervolume voorspellings op ekonomiese aktiwiteit te baseer, dit wil sê gevalideerde vraag, en nie op die waargenome werklikheid van historiese houers of ander breë aanwysers nie.

Die gemengde metode ontwerp kombineer literatuur oor houermodelleringstegnieke, vraagkant- en aanbodkant-houer verskepingsfaktore en die impak van hawe netwerke op kaaimuurhouervolumes. Die literatuur het slegs 'n paar aktiewe navorsers getoon in die veld van hoë diepte houer voorspellingsmetodes. Diegene wat metodes voorgestel het, het hoofsaaklik afgeleides van verhandelde kommoditeite gebruik, soos BBP-, handels- of bevolkingsgroei as insetdrywers. Baie navorsers verwys na, maar baie min gebruikte houerinhoud in hul modellering, meestal weens die onbeskikbaarheid van data.

Ryk sekondêre datastelle wat van verskillende partye ontvang is, soos TNPA, SARS, TFR en skeepsrederye, was instrumenteel in die verstaan van die relevante parameters. Alle datastelle het op hul eie manier bygedra tot die ontwikkeling van die finale stel parameters. Om hierdie sekondêre data te ondersteun, is primêre navorsing gedoen met vrageienaars, bedryfsverenigings, Logistieke diensverskaffers, rederye, hawe owerhede en terminaal operateurs via 'n opname en fokusgroepe. Terugvoer van opname respondente en fokusgroepe het die gebruikersvereistes wat voor hierdie gebeure geïdentifiseer is, bevestig. Dit het ook die belangrikheid van die geïdentifiseerde vereistes en die insette wat verkry is om die inhoud van die houerinhoud te ontleed, bevestig.

Ontwerpvereistes is gekonsolideer uit al die navorsingsinsette vir gemengde metodes. Sleutelparameters om volhouervolumes oor die kaaimuur te voorspel, is:

- Ruimtelike disaggregasie om uitsette per internasionale geografiese streek en per hawe te definieer;
- Verhouding van houerverpakking van elke kommoditeit;
- Kommoditeits hawe voorkeur;
- Fisiese houertipes;
- Gewig van kommoditeit per fisiese houertipe.

Die raamwerkmodelleringsraamwerke en modelleringsproses vir drie funksionele tipes, is ontwikkel op grond van die ontwerpvereistes. Die insette, parameters, modelleringsproses, voorspellings-invloede en uitsette vir elk van die gedefinieerde funksionele tipes is afsonderlik bespreek met 'n vertroue vlak vir elk van die aspekte. Die vertroue vlakke gee 'n aanduiding van die huidige status van die parameterwaardes en bied leiding oor toekomstige verbeterings.

Die houermodelleringsraamwerk het 'n verifikasie- en valideringsproses gevolg. Die model sal na verwagting 'n meer akkurate houervoorspelling vir haweinfrastruktuurbeplanners voorsien. Die gebruik van hierdie drywers in voorspellingsmodelle sal hawebeplanners van gevalideerde vraag inlig om berekende besluite te neem oor die inisiëring van hawe houerinfrastruktuurprojekte op die regte oomblik in tyd.

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LIST OF ACRONYMS/ABBREVIATIONS

AIDC	The Automotive Industry Development Centre
BEC	Broad Economic Categories
CGA	Citrus Growers Association
FCL	Full container loads
FDM	Freight Demand Model
FFU	Forty Foot Unit (container size)
FEU	Forty foot Equivalent Unit (used as equalising unit for all sizes)
FTSE	Financial Times Stock Exchange
GDP	Gross Domestic Product
GICS	Global Industry Classification Standard
ICB	Industry Classification Benchmark
ISIC	International Standard Industrial Classification
JICA	Japan International Cooperation Agency
LCL	Less than container load
LSP	Logistics Service Provider
LTPF	Long term planning framework (Transnet)
NACE	Statistical Classification of Economic Activities in the European Community
NAICS	North American Industry Classification System
NATO	North Atlantic Trade Organisation
n.e.s	not elsewhere specified
OD	Origin-Destination
OECD	Organisation for Economic Co-operation and Development
PPECB	Perishable Products Export Control Board
ROI	Return on Investment
RORO	Roll-On Roll-Off (terms used for fully built automotive vehicle shipping)
SADC	Southern African Development Community
SARS	South African Revenue Services
SIC	Standard Industrial Classification
SITC	Standard International Trade Classification
STS	Ship to Shore
TEU	Twenty foot Equivalent Unit (used as equalising unit for all sizes)
TFU	Twenty Foot Unit (container size)
TFR	Transnet Freight Rail
TNPA	Transnet National Port Authority
TPT	Transnet Port Terminals
TRBC	Thomson Reuters Business Classification
ULCS	Ultra Large Container Ships
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNSD	United Nations Statistical Division
UNSPSC	United Nations Standard Products and Services Code
WCO	World Customs Organisation

1. Introduction

1.1 Background

Globally, unabated population growth, urbanisation, and resulting increased consumption is expected to intensify growth in freight transport volumes (Ivanova, 2014), exacerbated by the reality that transportation infrastructure is approaching capacity levels (Müller, Wolfermann, & Huber, 2012).

Approximately US$2.5 trillion is invested per annum in the world's transportation, power, water, and telecommunications infrastructure. Yet this amount continues to fall short of the world's ever-expanding needs, resulting in lower economic growth and limiting access to essential services (McKinsey & Company, 2016). According to research by the WorldBank (2016a), the global infrastructure investment gap amounts to at least US$1 trillion per year. This corresponds to about 1.4% of global GDP. McKinsey & Company (2016) estimated that from 2016 through 2030, the world needs to invest about 3.8% of GDP, or an average of US$3.3 trillion a year in economic infrastructure, just to support expected rates of growth. Emerging economies account for approximately 60% of that need. However, if the current trajectory of underinvestment continues, global investment needs will fall short in the region of 11%, or US$350 billion a year.

From a transportation infrastructure perspective, a more efficient logistics system is one of the key pillars to support national economic prosperity. Zaman and Shamsuddin (2017), for example, estimated that timeliness of logistics has a significant impact on per capita income. Coto-Millán et al. (2016), using Logistics Performance Index (LPI) data, estimated that every 1% increase in LPI, *ceteris paribus*, increases domestic technical efficiency by 0.59%. Njoh (2009) argued that a strong causal link exists between transport infrastructure availability and economic development. This concept is confirmed by Ryckewaert (2010) in his post-analysis of the ten-year port planning of Antwerp from 1956–1965, where he indicated that the port infrastructure plan was primarily a trigger for economic development. According to the Worldbank (2016b), logistics- and connectivity-related interventions have the highest potential to reduce trade costs and to boost global value chain integration. This role is enabled within specific country contexts and at detailed industry or geographical levels.

Average GDP growth for South Africa equalled 2.1% between 2011 and 2015. The latest growth estimate for 2016 is, however, only 0.3%, with a slight recovery to 1.0% forecast for 2017 (Statistics South Africa, 2017). These growth rates are in sharp contrast to those of the developing Asian economies, with China's growth expected to remain at 6.7% in 2017, the same level as in 2016, and to decline modestly in 2018 to 6.4%; while growth rates in India are expected to remain around 7% (IMF, 2017). To reach South Africa's National Development Plan target of creating 11 million jobs by 2030, an average annual GDP growth rate of 5.4% between 2012 and 2030 is required (Phakathi, 2017).

The country's Industrial Policy Action Plan places an accelerated focus on increasing value-added manufacturing exports due to the strong resulting economic and employment multipliers, as well as to reduce the volatily of resource-led growth due to commodity price cycles. This is strongly associated with South Africa's beneficiation strategy to utilise the country's abundant natural resource endowment across the entire value chain, building competitive advantages and linkages between the productive sectors of the economy. There have been notable successes in export growth in clothing, leather and footwear; biotechnology products; fresh fruit exports, automotive components and agro-processing beverages (mainly wine and juice). Other focus areas include plastics, chemicals, pharmaceuticals and cosmetics, and the steel and metals sectors (Department of Trade and Industry, 2017).

Port logistics and efficiencies are a key enabler of these value-added exports. In turn, manufacturing also supports and sustains investment into logistics and related infrastructure, mutually reinforcing the country's economic growth potential and job creation ideals (Department of Trade and Industry, 2017). This is also aligned with the United Nation's Development Goal 9, i.e. the building of resilient infrastructure, promoting inclusive and sustainable industrialisation and to foster innovation (United Nations, 2017).

The value-added manufacturing industries targeted to enable South Africa's growth trajectory are a natural market for containerisation due to increased delivery speeds, improved security and decreased damage of goods. In addition, reefer containerisation enables growth of perishable exports. The potential for reduced supply chain costs due to decreased fragmentation, reduced cargo handling and losses, improved productivity of transport assets (road, rail and ship) and lower opportunity costs of inventory is also an enabler of economic growth by rendering industries more competitive through reliable and efficient distribution channels (Nurosidah, 2017).

In order to unlock these opportunities, Transnet Port Terminals (TPT) is planning to invest R50.3 billion over the 7-year cycle 2017/18 to 2023/24, with approximately two-thirds of the total allocated to capital expansion and the remainder to replacement capital expenditure. Half of this expenditure will be at the four major container and break-bulk ports, namely the ports of Durban, Ngqura, Port Elizabeth and Cape Town. TPT expenditure amounts to between 15–20% of the total rolling 7-year Transnet Market Demand Strategy (MDS) (Transnet, 2016), of which the latest estimate, released with the 2016/17 Transnet annual results, amounts to R278 billion (Transnet, 2017). A key component of this expansion is to dig out the old airport site in the South Durban basin, 8 km to the south of Durban, South Africa's largest port, and develop a dedicated container port. There is, however, still significant uncertainty regarding the time frames and investment required. Early in 2015, Mark Gregg-McDonald, Transnet's group executive of planning and stability, mentioned 2021 as a starting date to be ready for capacity constraints expected in 2025 (Container Management, 2015). In 2013 Transnet National Ports Authority announced plans for the Durban dig-out port somewhere between 2019 and 2042, a much wider time frame (Mather, 2013). In September 2012, when Transnet announced the plans for the Durban dig-out port, it was met with much antagonism (Back of Port Harbour Development, 2012; Business Day Live, 2015). Reported budgets for the new port vary from R70 billion to R100 billion. Informing this substantial investment will be a core focus of the port planning process going forward.

Transnet's average annual capital expenditure over the next 7-year period (i.e. 2017/18 to 2023/24) amounts to approximately 1% of 2016 GDP – a very significant contribution to national infrastructure investment when compared to the global infrastructure investment/GDP ratios mentioned earlier in this chapter (South African Reserve Bank, 2016).

The key principle of Transnet's MDS is to meet validated market demand through capacity creation and infrastructure investments. The concept of validated demand is driven by the requirement to optimise capital expenditure through ensuring financial stability and agility (Transnet, 2017). The challenges with validated demand have been evident in the growth volatility of South Africa's international trade in containers over the past five years. Despite strong year-on-year growth of 10% between the first quarter of 2016 and the first quarter of 2017, the 2017 market size is only 5% larger than the 2013 market size. Growth in container trade has therefore only been around 1% per year over the last five years (Fin24, 2017).

According to McKinsey & Company (2016) fact-based projection alone can reduce infrastructure investment needs by up to 8%. Validated demand through fact-based forecasting is, however, an elusive concept in the forecasting of container demand. In the next section, the challenges in forecasting container demand are elucidated.

1.2 Global container forecast challenges

Havenga and Van Eeden (2011) indicated several forecasts that were adjusted significantly from year to year. One example is Gardiners downsizing their 5-year forecast of 10% per annum from 2006 to 5% per annum one year later (Drewry, 2008). Gardiner's lowered forecast in 2007 for 2012 volumes was still overstated by approximately 23% based on the total throughput of 589 million TEUs at ports worldwide in 2011, a growth of 7.2% from 2010 (Drewry Maritime Advisors, 2013).

Singh (2005) forecast a decade ago that demand for container port capacity will outstrip supply by 2012 and that a doubling of global port capacity will be required between 2005 and 2012. This was before the global recession, and in 2010 overcapacity still existed (Neylan, 2010). Ocean Shipping Consultants (2011) forecast overcapacity in most European container ports up to 2020, initiated by the fallout of the 2008 recession. Despite the recession, world container traffic, however, still grew by 4.2% between 2008 and 2010 (Neylan, 2010).

An Indian Ports Association (IPA) working paper shows a 20-year container forecast compiled in 2007 by Jawaharlal Nehru Port Trust (JNPT) (Raghuram & Gangwar, 2007). This study used 2006 as base volume and forecast container throughput for the combined Indian ports of 23 million TEU by 2016. This included 12 million TEUs of direct shipments, and 11 million in transhipments and hub transfers. Upon investigation of actual 2016 container volumes through all Indian ports, the Indian Ports Association (2016) reported for April 2016 a throughput that equates to annual volumes of 9.0 million TEUs. It is not clear from the data obtained if this includes both transhipments and hub transfers. Even if the IPA volumes for 2016 only reflect direct shipments, the 10-year forecast from 2007 overstated the throughput by 34%. If the current 9 million volumes includes all TEUs, the overestimation is 155%. The reason for this gross overestimation is basing the forecast on one parameter, i.e. extrapolation of historic container growth rates.

In August 2015, Neil Davidson, Drewry`s Senior Analyst for Ports and Terminals (Drewry is the leading supplier of consolidated information in the global shipping industry) (Portnews, 2015) predicted an average annual global increase in container demand of 4.5% up to 2019. This would add an additional 168 million TEUs to the 682 million TEUs of 2014 (Portnews, 2015). While their forecast could demonstrate the resilience of global container trades, capacity creation should proceed with caution given the margin of error in recent forecasts.

In an exploratory study for South Africa, Havenga and Van Eeden (2011) illustrated that extrapolated container volumes outstrip a ‘100% containerisation of all traded commodity content’ scenario by a factor of between two and three times over a 30-year forecast horizon (Figure 1.1). These scenario outliers confirm the risks with extrapolated forecasts and the need to develop more robust container forecasting techniques.

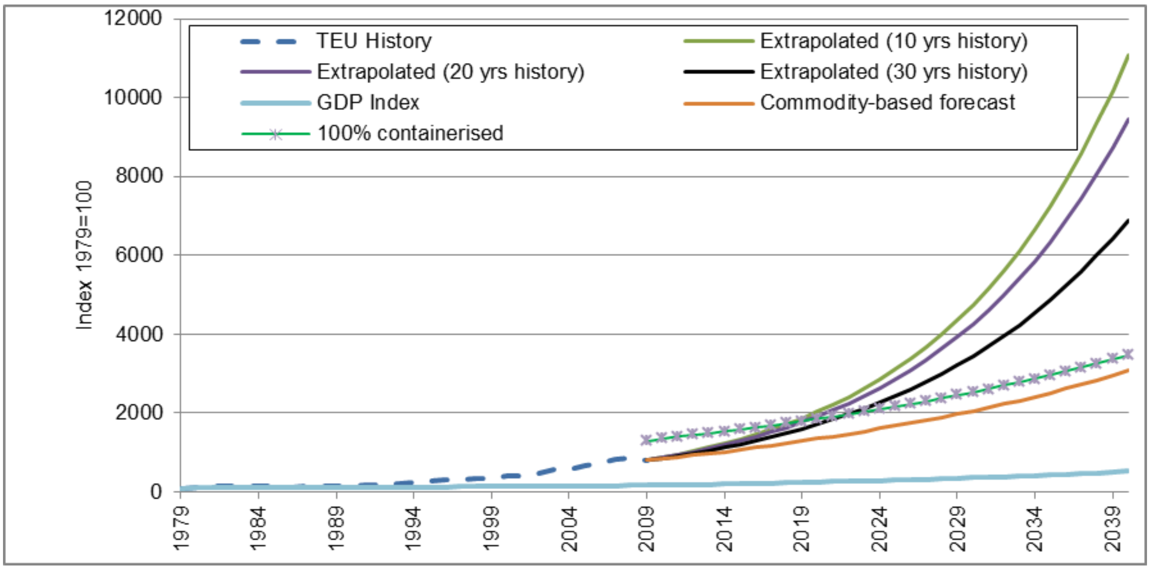

Figure 1.1: Extrapolated container- versus commodity-based forecast for South African ports with ceiling container volumes (Havenga & Van Eeden, 2011)

The impact of overly optimistic forecasts is also reflected in shipping line behaviour, causing overcapacity challenges, as summarised in the next section.

1.3 Supply side: Global shipping infrastructure

Davidson, explained that: 'The global container terminal industry is facing unprecedented challenges as a result of the deployment of ever larger container ships, combined with the creation of larger shipping line alliances. These two interrelated factors are placing significantly greater demands on ports and terminals and have far reaching consequences, driving up operating costs and capital expenditure requirements' (Portnews, 2015).

During the unprecedented global economic growth experienced between 1995 and 2007 (World Bank, 2016a) global shipping infrastructure emphasis was on building bigger container ships with capacities that had never been seen before. Shipping lines are continually investing in larger ships with bigger carrying capacity and improved efficiencies. The biggest container ship to date, the *OOCL Hong Kong* with 21 000 TEU capacity was delivered in May 2017 (OOCL, 2017). This has been the fourth container ship with a capacity over 20 000 TEU taken into service. Drewry Maritime Research (Drewry, 2015) sees this trend of bigger ships continuing into the next decade, requiring the subsequent upgrading of port channels and quayside infrastructure to accommodate the larger ships. Multiple large investment projects have been initiated over the past few decades to accommodate these bigger ships. Many of these projects involved port, rail and road infrastructure development in formerly less developed world regions, i.e. Central Africa, Eastern Europe, Latin America and China (World Bank, 2016a). Examples are the intermodal impact of the widening of the Suez (Mostafa, 2004) and Panama canals (Salin, 2010).

Since the 2008 global financial crisis (Guttal, 2012), the weak global economy negatively impacted the demand for trade and container movements, with commodity prices also falling. The high number of larger container ships entering the supply side of the equation led to an oversupply situation. This caused a decline in shipping rates over the last two years to levels last seen just after the 2008 global financial crisis. Drewry believes this trend will continue on many shipping routes over the next couple of years in search of a new supply-demand balance (Drewry, 2016).

Senior editor for JOC, Greg Knowler, (Journal of Commerce, 2016) reports that many container carriers in 2015 ramped up scrapping of older smaller ships as demand and rates keep on waning. This was done in an attempt to correct the oversupply of container capacity. Figure 1.2 shows the capacity of container ships scrapped in the last 7 years, and Figure 1.3 shows the ship size split for 2016. According to Drewry, the rate of scrapping started slowly in 2015, but it picked up momentum towards the end of 2015 and continued into 2016. What was new is the size and relative youth of some of the scrapped ships. A total of 151 ships at an average age of 19 years were scrapped in 2016 up to 7 November. Data showed that by November 2016 ships totalling 520 000 TEUs had been scrapped, including more than 60 ships in the range of 4000–7000 TEU (Marinelink, 2016).

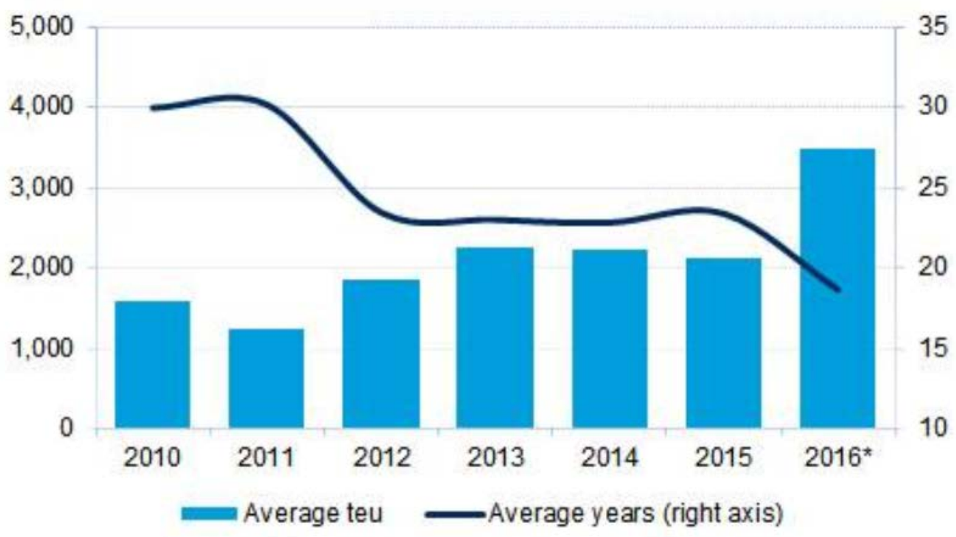

Figure 1.2: Container ship demolitions by year (TEU) (Marinelink, 2016)

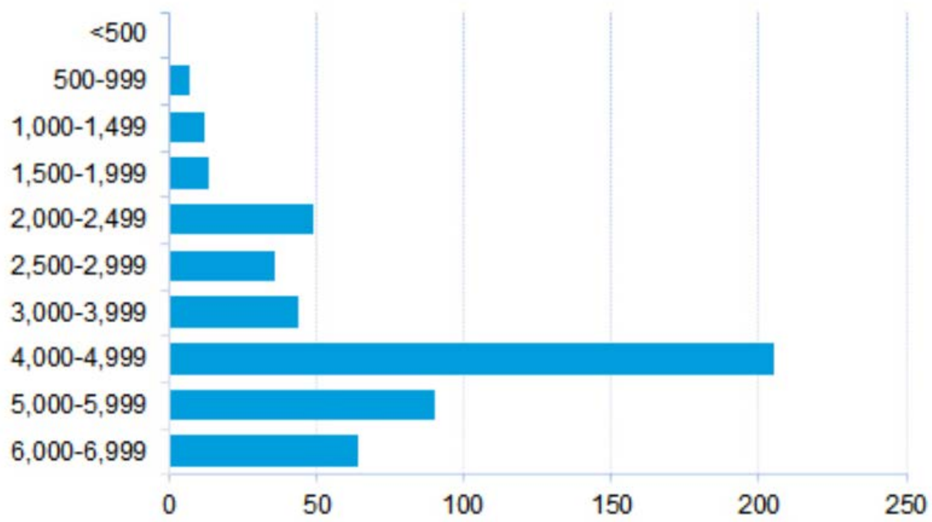

Figure 1.3: Container ship demolitions in 2016 by size range (TEU) (Marinelink, 2016)

In order to investigate potential reasons for these forecasting errors, an overview of forecasting techniques for international trade containers is provided in the next section.

1.4 Forecasting techniques for trade container demand

The most common approach to forecasting trade container demand is the strong belief that it is 'ultimately driven by economic growth' (UNESCAP, 2007). The underlying assumption in the UNESCAP forecast is that, for the decade up to 2017, 'the structural relationships between growth in container trade and economic growth will remain basically unchanged'. The basis of their analysis was consequently expectations of future economic growth (UNESCAP, 2007). The Department of State and Regional Development of New South Wales (2011), responsible for container forecasts for Melbourne, Sydney, Brisbane, Fremantle and Adelaide, also bases dramatic intermodal growth on globalisation and world economic growth, which is forecast to remain constant over the next 20 years.

The United Nations forecast is for a global outcome, but some major ports such as Rotterdam (where commodities are considered) and New York (where the 'economic wellbeing of surrounding hinterland states' as well as foreign trade volumes are considered) – (Dagenais & Martin, 1987) developed more complex forecasting models. Gosasang et al. (2010) refer to Japan International Cooperation Agency’s (JICA) forecast reports of 1994, which forecast volumes of import/export containers at Bangkok Port by using the technique of regression analysis on the two variables of population and gross domestic product (GDP). They proposed a neural networks method for predicting the container throughput at Bangkok Port, but still considered domestic GDP, world GDP, the exchange rate (compared with the US dollar), population, inflation rate, interest rate and the fuel price as underlying variables.

Fung (2001) adopted a forecasting model that considered price sensitivity and service competitiveness between the competing ports of Hong Kong and Singapore, with GDP growth as a given. Wilson and De Vuyst (2007) also emphasised inter-port competition in the USA and highlighted a common mistake entailing a belief that certain forecasts relating to the improvement of efficiency levels will correlate with growth, while port competition is ignored.

Lam et al. (2004), in addressing the ever-present issue of forecasting demand for Hong Kong, one of the world’s busiest container ports, proposed in 2004 that explanatory factors (such as population, trade values of imports/exports, and GDP) that affect freight movements should be reanalysed since the relationship between these and freight movements was determined in 1997. He reasoned that changes in the economic environment 'might cause their relationship to no longer be valid, and hence a reanalysis is needed'.

In forecasting container throughput for Indonesia to support the case for the building of a new port, Syafi’i, Kuroda and Takebayashi (2005) included container throughput, GDP, population, and exports and imports as model variables and assumed that the statistical structure of the model would not change substantially in the future. Wilson and De Vuyst (2007) maintained that 'rather than modelling individual or even multiple commodities, we explicitly recognise that the supply and demand for container shipments is a market of its own, regardless of the contents of the containers'. However, the authors do list as an outstanding issue the 'non-identity of container content' and concede that the reason their model excludes commodities is because the content of containers is unknown. They go on to state that 'there has been an increase and shift in commodities shipped by containers' and suggest that 'somehow this will have to be captured in the model specification' (Wilson & De Vuyst, 2007). Garratt (2006) referred to the slower growth rate of containerisation due to the 'maturing of the containerisation of commodities'.

Rodrigue and Notteboom (2015) also emphasised that the shipping container is maturing in its position as a freight transport medium and is the first choice for most deep-sea shipping. They argue that the historic exponential growth trends in the container market included substitution growth where bulk freight movements have moved into containers, in addition to organic growth from the transport of manufactured goods.

Future growth will therefore either be induced or pure organic growth, i.e. economies will either intervene to stimulate trade growth, or alternatively growth will be due to trade partner natural consumption growth. Both these growth drivers are linked to the contents of containers, which is currently underrepresented in container demand forecasting (Rodrigue & Notteboom, 2015).

Garratt (2006) and Rodrigue and Notteboom (2015) refer to the key underlying drivers for international trade container demand in their outlook, i.e. the propensity to containerise commodities in the wake of increasing globalisation. Over the past 30 years, growth in global container flows significantly outperformed global GDP growth, as is illustrated in Figure 1.4, below.

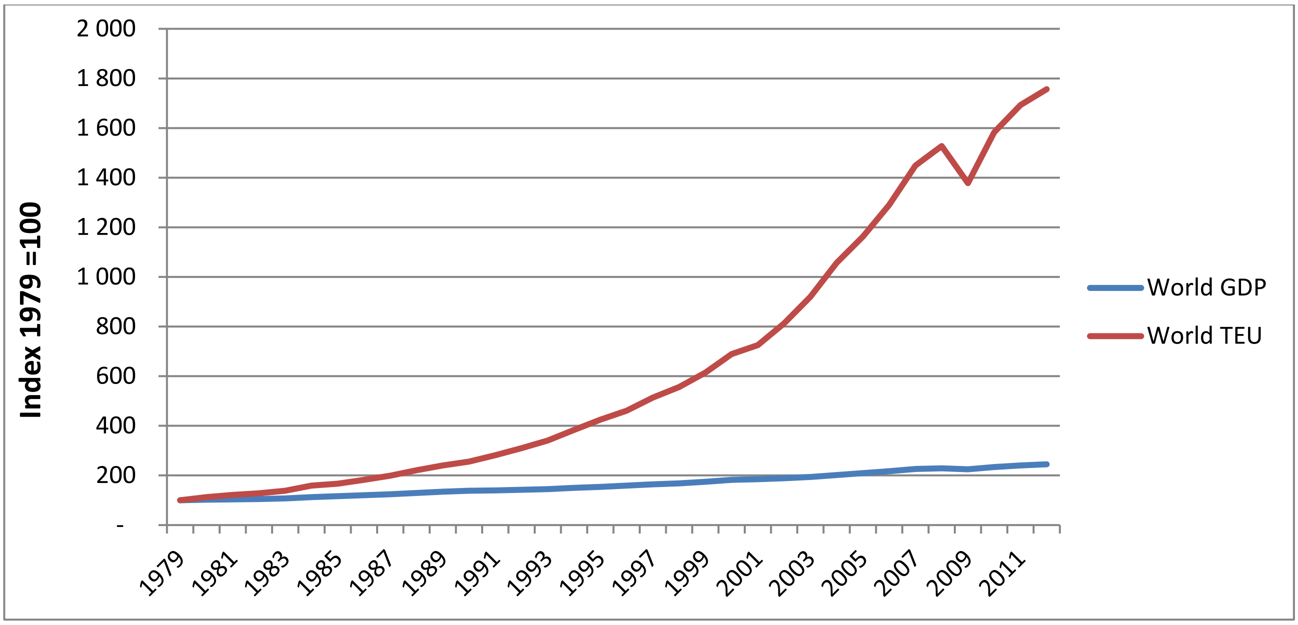

Figure 1.4: Growth in global container flows outstripping GDP growth over the last three decades (GDP data from IndexMundi (2016); TEU data from Sooredoo (2013)

However, a review of individual countries reveals that container growth in developing countries has been much higher than in developed countries over the same period. This phenomenon can be seen in Figure 1.5, for India and Brazil, representing developing economies versus the UK and the USA, representing developed economies. One reason for this is that the containerisation trend started earlier in the developed world, pointing to the natural slowing down of containerisation over time referred to previously.

Transnet National Port Authorities (TNPA) port statistics (2017) also indicate that South African bulk freight is stagnating or declining, while all trade growth has been directed at container movement for the past couple of years.

In the research presented in this dissertation, the inevitable saturation in the propensity to containerise is hypothesised to be a potentially important explanatory factor in forecasting container demand. Factors such as the correlation between aggregate GDP growth and container growth, and increasing ship sizes are observable, 'tip-of-the-iceberg' indicators. Trends in the demand for container transport are, however, driven by shifts in underlying economic structures (due to innovation and ultimately shifts in final consumption patterns). The latter 'hidden' indicators point to the need to understand the underlying sectoral and geographical economic activity that informs the demand for containers as a transport medium, as well as understand which external factors can impact this demand.

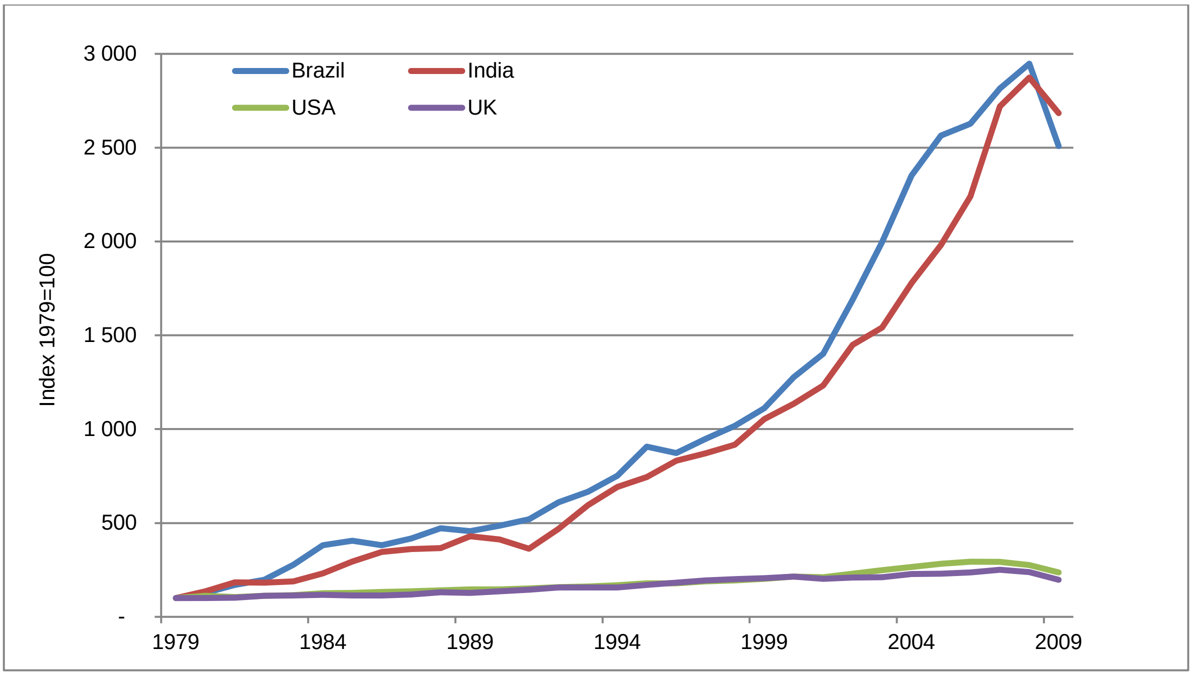

Figure 1.5: Relationship between GDP and TEU growth for developing and developed countries (GDP data from IndexMundi, 2011; TEU data from Sooredoo, 2013) (No newer detail per country available)

It is this heterogeneity of freight and geographies that render freight transport demand modelling more challenging from a methodological point of view than passenger transport demand modelling (De Jong, Gunn, & Walker, 2004) (Ivanova, 2014) (Müller, Wolfermann, & Huber, 2012). This is compounded by the mega scale and extended lifespan of freight transportation infrastructure such as railways and ports (Rodrigue, 2016). Freight transport modelling should commence from economic linkages, as freight transportation is an outcome of economic interactions (Tavasszy & De Jong, 2014). Three decades ago Raza and Aggarwal (1986) understood that aggregate freight-flow analysis cannot reflect the diversities of and the disparities in either the production or consumption processes, nor can they reflect the regional structure of an economy. Empirical literature on freight demand modelling continues to focus on aggregate trade flows, hampering the development of policy-relevant conclusions related to specific infrastructure categories or industries (Ivanova, 2014). Access to reliable, sectoral freight-flow information informs a deep understanding of the current and possible future states of a nation’s freight transport system, and enables the design and implementation of freight policies and investments to deliver on a chosen future state (Tavasszy, 2006) (Tavasszy & De Jong, 2014). The forecast of the demand for trade containers forms part of the investment component subsequent to freight-flow modelling, i.e. which of the modelled freight flows are suited to the use of containers as a transport medium (enabling intermodal transport).

The shortcomings in the current empirical literature relating to container demand forecasting (as highlighted in section 1.4 and discussed in detail in Chapter 3) encouraged the development of a commodity content-driven forecasting model for global and South Africa's demand for international trade container capacity to inform infrastructure investments. In order to provide context for the research, a concise overview of South Africa’s port sector is provided in the next section.

1.5 South African ports – an overview

Transnet is the owner and operator of South Africa's port, rail and pipeline infrastructure. TPT operates 16 terminals in eight ports spread around the South African coastline, as illustrated in Figure 1.6. Operations are divided into four major business segments, namely containers, bulk, break-bulk and automotive.

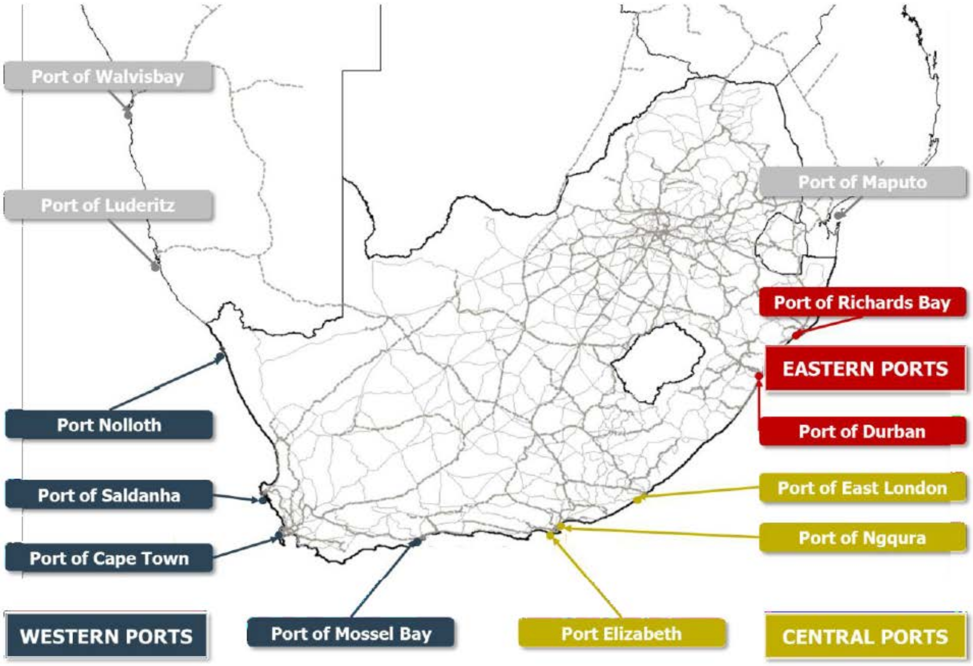

Figure 1.6: South Africa's port system (TNPA, 2017)

South Africa’s ports are thus not in competition with each other as is the case internationally. The integrated network of eight ports therefore has to satisfy total future demand with integrated port infrastructure planning. This joint planning and information sharing facilitates forecasting, but at the same time it increases responsibility. In the short- to medium-term, no alternative to poor planning exists. The ports of Maputo and Walvis Bay are possible alternatives in the medium- to longer-term, but competition from these two ports at current volumes is negligible compared with volumes in South Africa. (For details on Walvis Bay refer to the Japan International Cooperation Agency (JICA) (2010); and for Maputo refer to Mpumalanga Department of Public Works, Roads and Transport (2009).)

South Africa’s ports can be broadly divided into three categories. First, multipurpose ports that handle a variety of commodities i.e. unitised cargo in containers as well as break-bulk and in some instances bulk cargoes at specialised terminals. Secondly, dedicated bulk export ports that focus on handling one main commodity (although they do handle smaller volumes of other commodities). Thirdly, a port developed predominantly for future transhipment cargo, namely the Port of Ngqura (SAMSA, 2012). The Ports of Durban, Cape Town, Port Elizabeth and East London are classified as multipurpose ports, while the Ports of Richards Bay, Saldanha and Mossel Bay are classified as dedicated bulk export ports. Table 1.1 shows a breakdown of the main cargo types handled by South Africa’s eight commercial ports, while Table 1.2 provides each port’s contribution to the total and container volume and value of trade, highlighting the dominance of the bulk export ports in terms of tonnage contribution and the dominance of the Port of Durban in terms of value-added trade.

Table 1.1: Main cargo types handled through South Africa's ports (SAMSA, 2012)

Port	Port category	Sector
Richards Bay	Dedicated bulk export port	Bulk (and some break-bulk)
Durban	Multipurpose port	Containers, automotive, break-bulk
Port Elizabeth	Multipurpose port	Automotive, containers, break-bulk
Ngqura	Transhipment port	Containers
East London	Multipurpose port	Automotive and break-bulk
Mossel Bay	Dedicated bulk export port	Bulk and fishing
Cape Town	Multipurpose port	Containers, break-bulk
Saldanha	Dedicated bulk export port	Bulk (and some break-bulk)

Table 1.2: Port contribution to volume and value of total trade and container trade (East London and Mossel Bay excluded, volumes are negligible) (data from the FDM)

2014 data	Durban	Cape Town	Port Elizabeth and Ngqura	Richards Bay	Saldanha
% of total tonnes	23.8%	3.2%	4.2%	41.1%	27.6%
% of total rand value	54.9%	8.1%	7.4%	22.0%	7.5%
% of container tonnes	69%	19%	10%	1.1%	0%
% of container value	70%	16%	12%	1.0%	0%

In 2014 Transnet moved 4.56 million TEUs across the eight ports in the South African port system. This is expected to increase to 6.8 million TEUs by 2024, an annual growth of 4.7% (TNPA, 2017). Forecasts at port and berth level are also important. The Port of Durban handled 2.66 million TEUs in 2014, 61% of South Africa's volume. This number is forecast to increase to 4.2 million TEUs by 2024 for the Port of Durban, an annualised growth of 4.3%. The current Port of Durban will at some stage run out of capacity, and has little space to expand due to the city of Durban at the back of the port. Various plans for both bulk and container terminal capacity expansions exist. These plans show different extended lifespans for the port space limitation. Container freight will then have to be diverted to alternative ports, such as the Ports of Richards Bay, Ngqura or elsewhere, unless additional capacity can be planned.

The Port of Durban was the major contributor to full international trade container exports in 2015 with 63% of export volumes followed by the Port of Cape Town with 23% (Figure 1.7). A significant shift can be seen with full export containers moving from the Port of Port Elizabeth to the Port of Ngqura, the latter contributing 9% by 2015. Major shipping lines cannot afford their ships stopping at both these nearby ports, and more container ships prefer to stop at the Port of Ngqura.

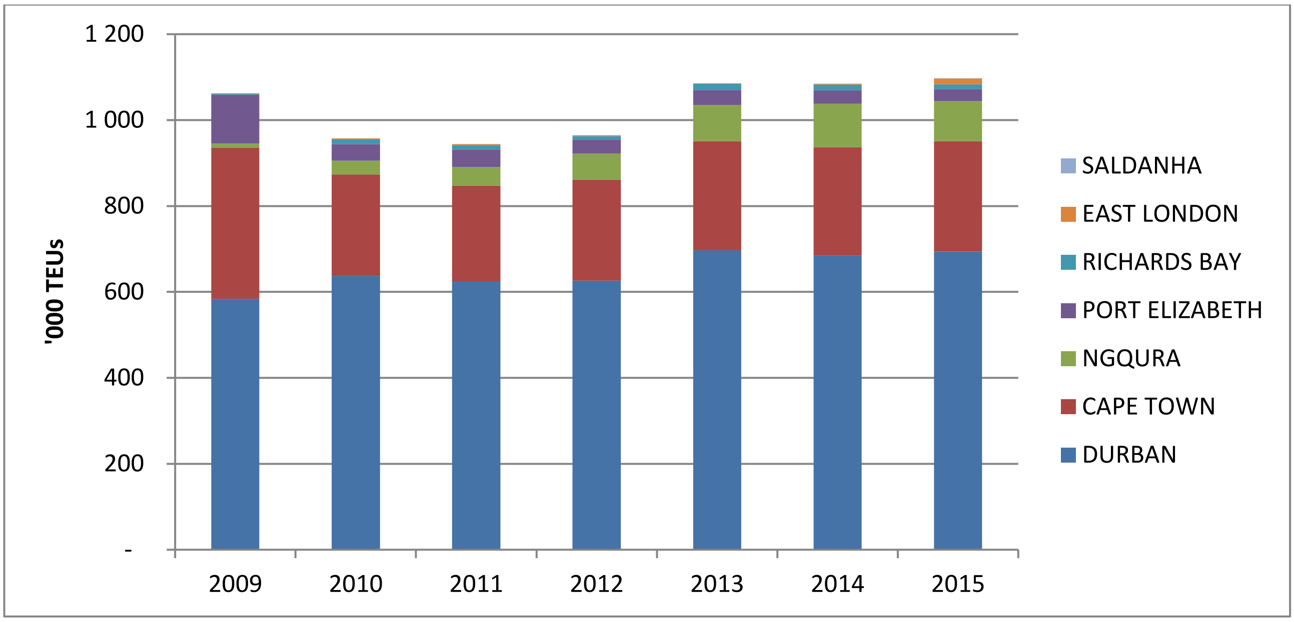

Figure 1.7: TNPA full export containers through SA ports

The Port of Durban was the major contributor to full international trade container imports in 2015 with 72% of import volumes followed by the Port of Cape Town with 16% (Figure 1.8). Again the shift can be seen with containers moving from Port Elizabeth to the Port of Ngqura, the latter contributing 8% of imported containers by 2015.

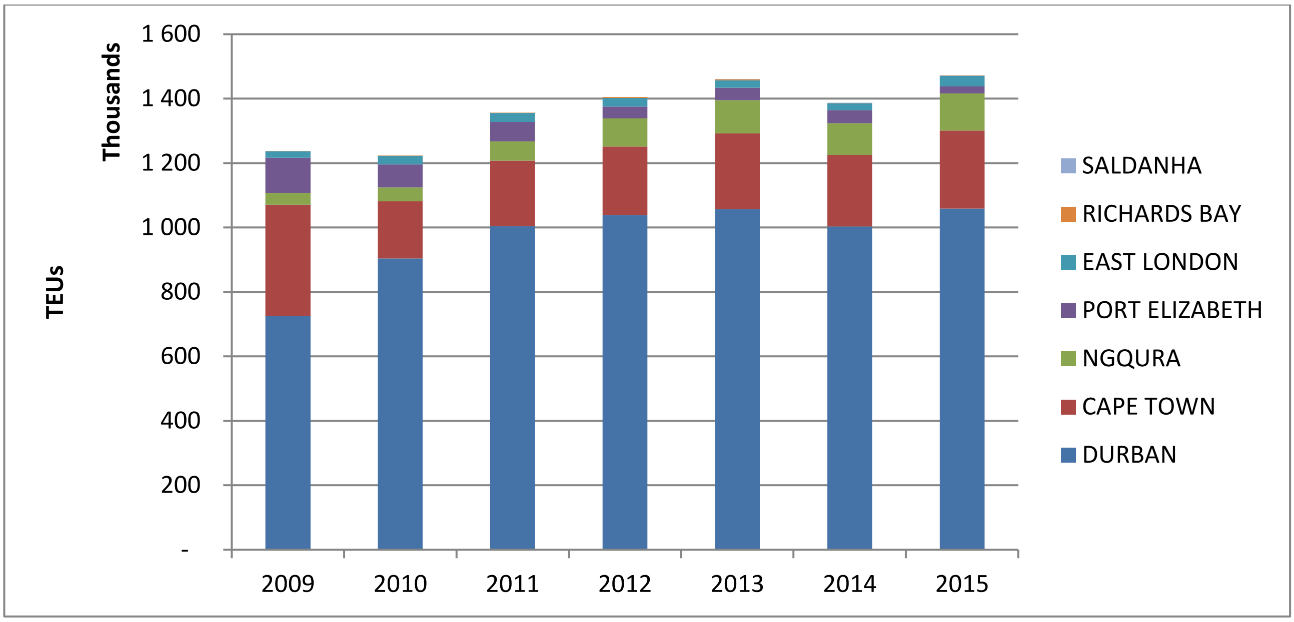

Figure 1.8: TNPA full import containers through SA ports

Transhipped, coastwise shipped and empty containers are often depicted as a percentage of the full containers per port by Drewry in their container reports and surveys (Drewry, 2008). Figure 1.9 indicates for the South African ports the contribution for these elements as a percentage of full containers:

- Transhipped containers: contribute an additional 15–18%;
- Imported empty: contribute an additional 8–12%;
- Exported empty: contribute an additional 17–21%;
- Coastwise shipped: contribute an additional 1–1.5%

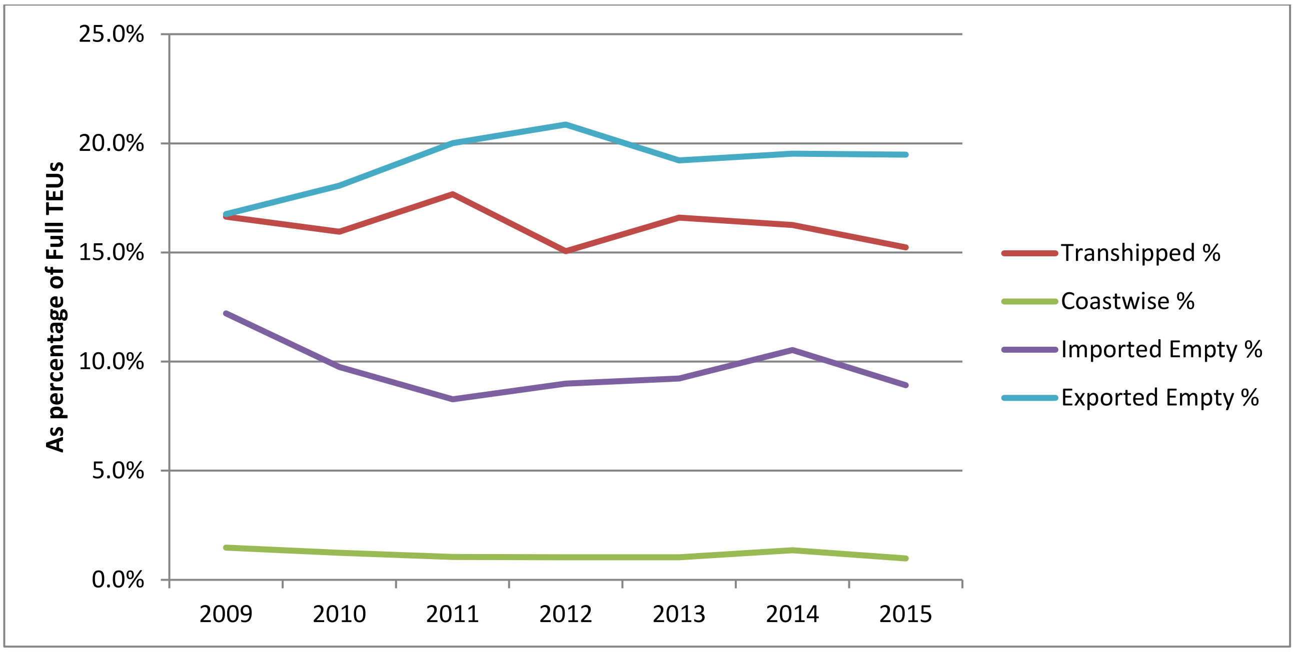

Figure 1.9: TNPA transhipped, coastwise and empty containers as percentages of full containers

The full marine deep-sea containers are the major contributor of container volumes at all the South African ports. This is thus the model that needs to be completed with the highest accuracy. The proposed inputs and outputs of such a model should be verified with port infrastructure planning professionals. These outputs should include medium- to long-term requirements from container users to ensure their accuracy. The transhipment and empty container segments contribute a significant portion of container volumes at all the South African ports. Transhipments and empties typically have a wide range of factors influencing their volumes which could make these models complex with little increase in accuracy over simpler methods. A sensitivity analysis should dictate whether the accuracy benefit of the more complex techniques does provide benefits that are worth the extended effort. Coastwise container volumes are negligible and will therefore not be included in this study.

1.6 Container forecasts in South Africa

Several years ago the various Transnet operating divisions developed their own forecasts, often with the assistance of different consulting groups and economists. This uncollaborated methodology led to different port volume forecasts due to different underlying principles and growth rates. These discrepancies usually lead to long debates. Collaborative and more accurate forecasts are required to ensure timeous infrastructure expansion. Transnet Group Planning subscribes to the philosophy that forecasts should be content-based, while the other Transnet entities use different methodologies.

The **Freight Demand Model (FDM)** used by Transnet to understand long-term freight forecasts has since 2007 included a container demand forecast (Havenga, 2007). This model is explained in the next chapter in more detail. The author has been involved over the last decade in developing the FDM as part of a team of researchers, but with specific focus on advancing the container forecasting methodology.

The FDM provides limited outputs to container modelling. The original container forecast in the FDM was not merely based on a GDP multiplier (as is common practice), but followed a more complex approach. It used the modelled flows of commodities and determined, based on broad assumptions, the percentage of each commodity that was packed into containers and the average container weight per commodity packaged into containers. The container forecast was thus commodity specific, although not as detailed as the one proposed in this dissertation. On a national level the FDM forecast has been satisfyingly accurate over the past years on the short-term; however, some concerns have been raised as to the effect of the lack of depth in the per port, per physical container type on the long-term forecasts.

Despite its national accuracy, the previous FDM container demand forecasting model could not provide the level of detail required for physical planning within Transnet. Some of the shortfalls of the previous approach listed by Transnet internal project documentation (Gain Group; Urban-Econ Development Economists, 2014) were:

- Parameter values for weight per TEU and percentage containerisation was based on small samples and little knowledge of the decisions made by freight owners.
- Forecasts were reported in Twenty-Foot Equivalent Units (TEU) only and were thus blind to the type of container used. For physical planning it is important to distinguish between types of containers as different types require different equipment and have different footprints.
- The earlier container forecasts were extrapolations of historic trends in South African container movement. Therefore, the forecast did not explicitly take into account changes in the underlying logistics decisions and global trends that could cause significant deviation from the extrapolated forecast.

For their medium- to long-term port infrastructure planning, Transnet requires a clear view of how international trade container movements will grow in volume and evolve in nature over the next 30 years.

1.7 Research framework

1.7.1 Research problem

The demand for containers as a transport medium is expected to continue increasing, impacting not only port capacity and service requirements, but also hinterland linkages. The lead time and lifespan of port infrastructure, i.e. the economic cost of 'failed' investments, necessitate the development of rigorous forecasting tools. The most common approach used internationally for forecasting the demand for international trade containers is models based on the correlation between container trade and aggregate economic indicators, i.e. using very low granularity input data. In the past two decades this approach has led to significant overestimation of future container demand, resulting in overcapacity in shipping and at ports.

There seems to be a lack of understanding of the underlying drivers for the demand for international trade. If these drivers are understood, more accurate port infrastructure planning can be done. Exponential growth in the demand for containers is expected to flatten due to a natural ceiling in the propensity to containerise commodities, leading to more organic growth levels.

In addition, there is a lack of knowledge regarding the macro-micro link of container demand. Freight owners' expected future requirements (as influenced by their organisational and supply chain strategies) should have an impact on the future transport network infrastructure investments. The current port infrastructure modelling parameters do not include supply chain user requirements and, where these are available in limited form, do not translate them into inputs for port infrastructure planning.

The research problem can therefore be summarised as follows:

> **Macro infrastructure forecasting tools used on container port level utilise very low granularity input data, and are often found to overestimate the demand for containers. These tools seldom use economic activity (i.e. container content) or inputs from micro level users and their specific future requirements in order to forecast the demand for international trade containers and subsequent infrastructure investments.**

1.7.2 Research aim

The primary aim of this study is to develop a commodity-based forecast model for full international trade containers, taking into account economic activity (i.e. the commodity-level propensity for containerisation) and the long-term requirements of shippers, to provide a more realistic medium- to long-term forecast of container demand to validate demand to inform port planning, large-scale port infrastructure investment decisions, and public-private collaboration opportunities.

The nature of the research, the access to data, and the analysis conducted, give rise to two secondary aims, i.e. to develop forecasting models for transhipped containers and empty containers to inform port planning and investments in South Africa.

1.7.3 Research objectives

In order to accomplish the research aim, the following objectives are set:

- Understand the state of the art in current container forecasting techniques and identify key learnings of relevance to this study;
- Identify current and future trends in the global container trade (demand-side) and container trade infrastructure (supply-side) landscape that are of relevance to this study;
- Identify data sources in the South African context that can be utilised both to inform and populate the forecasting models;
- Understand the supply chain decisions that freight owners make and how these are expected to influence trends in South Africa's international trade container landscape;
- Define design requirements for South Africa's forecasting model for full international trade containers;
- Propose and validate a container forecasting model for full international trade containers;
- Propose container forecasting models for transhipped and empty containers.

1.7.4 Research questions

Each research objective, in turn, is answered through a set of research questions. The list of research questions related to each research objective is provided in Table 1.3, with reference to the relevant chapter the research objective and question is addressed in the document.

Table 1.3: Research objectives and related research questions

Research objective	Research questions	Addressed in chapter
Understand the state of the art in current container forecasting techniques and identify key learnings of relevance to this study	• Which container modelling techniques are being used globally? • Which aspects of these models can be used as modelling inputs?	Chapter 3
Identify current and future trends in the global container trade (demand-side) and container trade infrastructure (supply-side) landscape that are of relevance to this study	• Which global trade, infrastructure and shipping trends will impact future container volumes? • Which other external factors influence the port container forecasts?	Chapter 4
Identify data sources in the South African context that can be utilised both to inform and populate the forecasting models	• What data sources are available and can be analysed to inform a better modelling approach? • How can content-based container data be used to improve container forecasts?	Chapter 5
Understand the supply chain decisions that freight owners make and how these are expected to influence trends in South Africa's international trade container landscape	• How did freight owner supply chain decisions impact historic and future container trends?	Chapter 6
Define design requirements for South Africa's forecasting model for full international trade containers	• What are the design requirements of a container trade forecast model in order to enable more reliable medium and long-term forecasts?	Chapter 7
Propose and validate a container forecasting model for full international trade containers	• How should the container forecasting model for international trade containers be designed in order to meet the design requirements? • How can the model be validated in order to determine whether it is sufficiently accurate of the system under study?	Chapter 8 Chapter 9
Propose container forecasting models for transhipped and empty containers	• How should the container forecasting models for transhipped and empty international trade containers be designed in order to meet the design requirements?	Chapter 8

1.7.5 Research limitations

The aim of the study is to develop a validated forecasting model for full international trade containers, and to propose models for transhipments and empties, not to forecast the container volumes themselves.

The following aspects are excluded from this study:

- The dynamics of the size and type of bulk and container ship populations;
- The road and rail infrastructure into and out of the ports;
- Domestic intermodal transport;
- Coastwise container transport due to its current negligible size and low potential in the foreseeable future;
- Rebalancing of the empty container population to where they are required for shipping;
- Developing specific investment plans for container ports and terminals based on container forecasts.

These factors have a major influence on South Africa's total container trade profile and are already the focus of various research initiatives.

While the detail of the sectoral and geographical disaggregated economic forecasting model of the South African economy is excluded from the scope of this dissertation, it is a core input into the container demand model. Key trade container demand and supply trends impacting on South Africa's economic forecast are identified, and serve as key influencers in the models. Close interaction between the economic forecasting model and the container demand model is imperative and already established.

1.8 Research methodology

A basic systems engineering approach was followed during this study to guide the development of the container forecasting model. For this purpose, systems engineering is defined as a logical sequence of activities and decisions that translate an operational need into a set of user requirements that need to be met by the model, followed by the development of the model, verification that the model met the requirements, and validation that the outputs provide 'a sufficiently accurate representation of the real system it is designed to reflect' (definition adapted from US Department of Defense, (2001), quote from Turnquist, (2006)) (refer Figure 1.10).

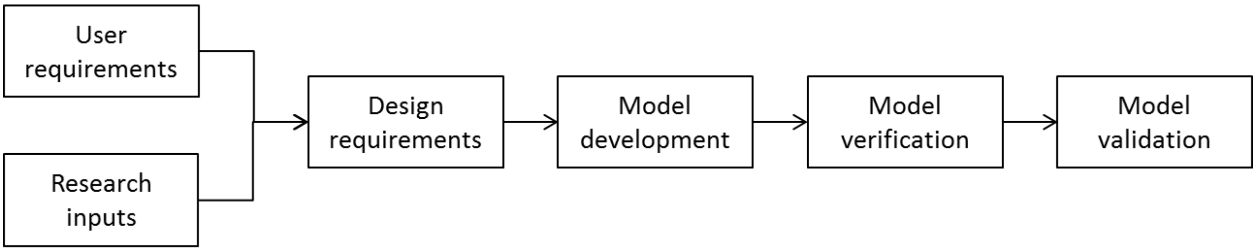

Figure 1.10: A simplified systems engineering approach for model development

The research design applied to enable this systems engineering approach is informed by Mouton's (2013) typology of research design types. The research is an empirical study, utilising secondary quantitative data analysis with primary data from a survey and focus groups.

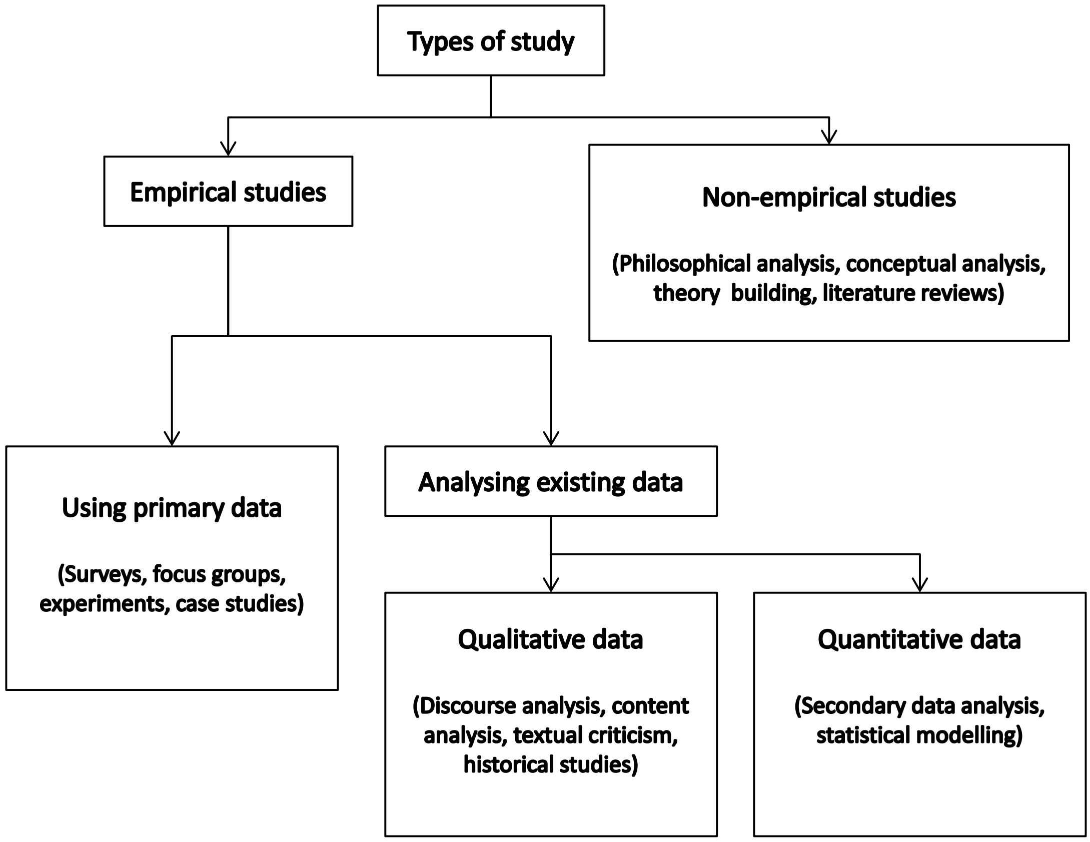

Figure 1.11: A typology of research design types (Mouton, 2013)

The combination of data types therefore renders this a mixed-methods research design due to the rich secondary quantitative data sources available for this study to inform the conceptual modelling framework for quay wall containers. Creswell and Plano Clark (2011) explain mixed-methods research design as 'a procedure for collecting, analysing, and "mixing" both quantitative and qualitative methods'. This process can be done in a single study or in a series of related studies to understand a single research problem. In the research problem identified the starting point is to analyse secondary data sources of historic container movements that are available to the researcher. The secondary quantitative data analysis phase will be followed by a primary research phase where inputs will be obtained from supply chain decision-makers through a survey and focus groups in order to identify parameters and influencers that could impact container volumes in the future. In addition, this process will serve to confirm the quantitative findings and clarify any remaining questions. Mixed-methods research is not about collecting and combining two separate 'strands' of research – qualitative and quantitative. Its focus and objective is about integrating and linking the two aspects. The sequence is as follows (Creswell & Plano Clark, Designing and conducting mixed methods research, 2011):

- The priority is on collecting and analysing secondary quantitative data.
- The second phase of the research follows a supplementary qualitative component.
- The qualitative data are used to refine the analysis outcome from the quantitative data. This refinement could result in exploring a few typical cases. Outliers or extreme cases found in the quantitative analysis can be explored in more detail.

Van Aken et al. (2006) distinguished five different types of requirements for framework design:

1. User requirements (U): Specific requirements from the view of the user which explain the constraints as well as how the framework will be used by the user;

2. Functional requirements (F): This forms the core of the requirement specification and is in the form of performance or result demands on the framework to be designed, that is, the functionality the framework is designed to perform;

3. Design restrictions (R): Requirements pertaining to the preferred solution space. The limits, exclusions, and elements of the design;

4. Attention points (A): The requirements that are relevant to the design and should be noted as desirable, but they are not requirements that have to be met, and are also not design restrictions;

5. Boundary conditions (B): The requirements/rules that have to be met unconditionally and may not be altered, e.g. legislation, ethical habits and code of conduct.

For the purposes of this study, the mixed-methods research design will inform the above requirements through detailed data collection and analysis in search of these aspects, as follows:

1. User requirements (U): Specific requirements from the view of the user of the forecast model will determine the required outputs of the model. This pertains specifically to port infrastructure planners (Model Outputs);

2. Functional requirements (F): The functional requirements of the container forecast model impacted by an analysis of the quantitative and qualitative datasets and informed by existing container modelling techniques to establish the key input parameters of the model (Parameters);

3. Design restrictions (R): The non-negotiable input requirements for a viable container forecast model. The proposed container model needs to interact with other surface freight forecasting models to obtain inputs and in providing inputs for other models. Thus it needs to adhere to design restrictions dictated by related models. (Inputs);

4. Attention points (A) and Boundary conditions (B): Trends in the local and global demand and supply landscape that will act as broad influencers on the container forecast model (Influencers).

These requirements translate into a concept modelling framework that resembles a basic input-output transformation process (refer Figure 1.12). Such a modelling framework would include:

- Input data,
- Modelling parameters with starting values for these parameters,
- Medium- to long-term influencers that will change the starting values of parameters,
- A transformation process to translate the inputs into outputs by using the parameters and values,
- Output values that can be used in detailed port infrastructure planning.

A forecasting framework of this extent will increase the accuracy of both the timing and the type of infrastructure requirements for container port infrastructure in South Africa.

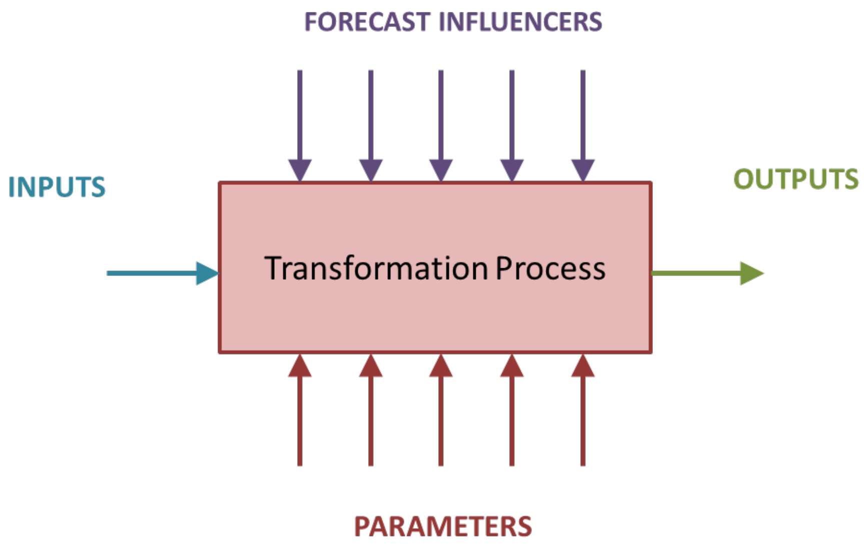

Figure 1.12: A concept modelling framework (adapted from US Department of Defense, 2001)

Figure 1.13 summarises the contribution of this study as the development of a new concept modelling framework to forecast container volumes. Inputs would be driven by economic input-output model data. Historic container content can be used to derive modelling parameters, while international container supply-side and demand-side factors will influence the values for these parameters now and in the future. Port planners need to be consulted to understand the user requirements that would be the essential outputs that the proposed model should generate.

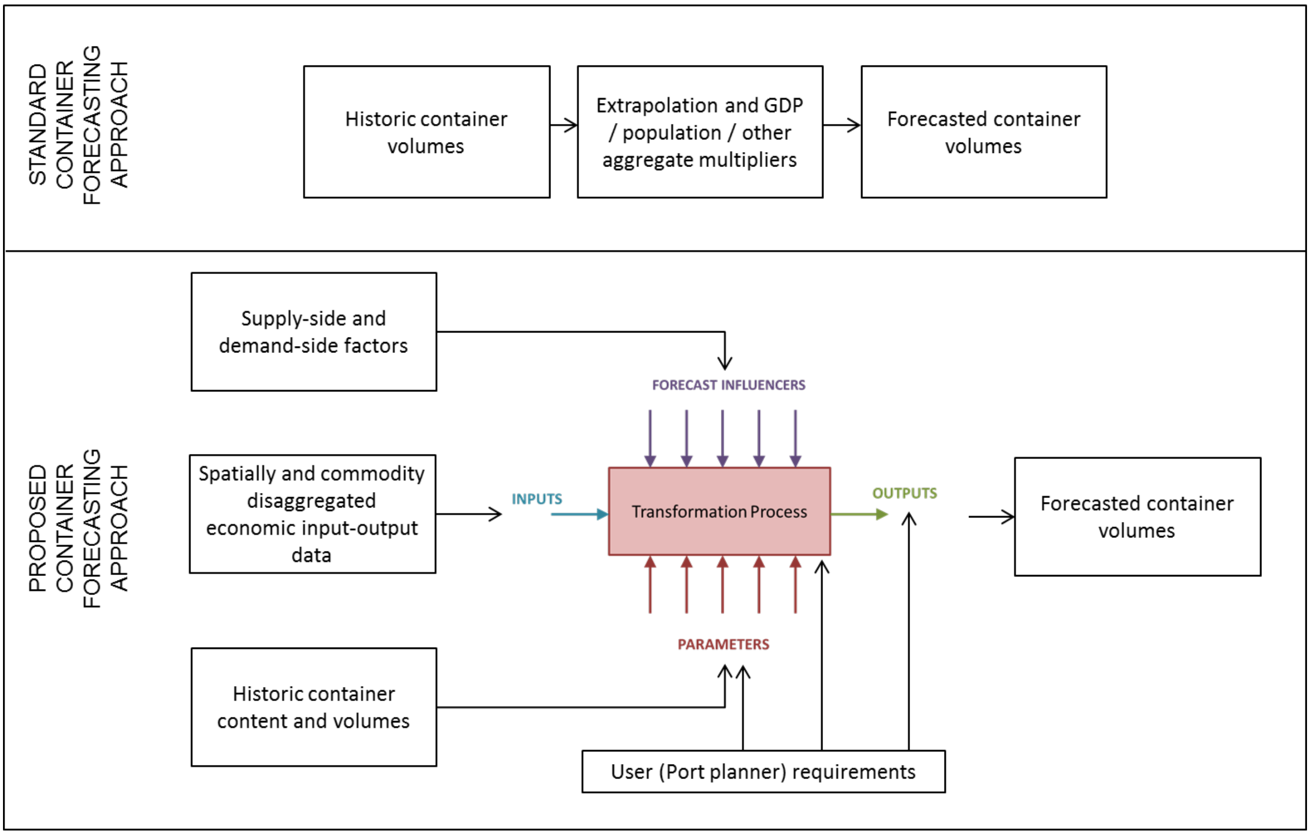

Figure 1.13: Contrast between current and proposed container modelling framework

1.9 Data collection and analysis

The research involves the collection of various datasets from industry. The secondary quantitative datasets were collected from Transnet divisions, shipping lines, SARS, economists and industry bodies. These datasets were analysed and interpreted using mostly inductive generalisation to develop parameters and input values for the modelling frameworks. Following on this process, an industry survey and focus groups were designed. The primary data collection through these processes led to both quantitative and qualitative datasets. These were analysed and interpreted as either confirmation of earlier findings or further inputs to the modelling framework. Throughout the process the literature inputs from Chapters 2, 3 and 4 were utilised to guide the analysis and interpretation.

These model drivers, combined with the economic forecasting model of the demand and supply for commodities in the South African economy, is expected to provide a more accurate container forecast to port infrastructure planners based on the content of containers. Using these drivers in forecasting models will inform port planners towards calculated decisions on initiating port container infrastructure projects at the right moment in time.

1.9.1 Secondary quantitative data

The first step was to understand the volumes and detailed contents of historic traded containers. Data sources that the researcher had access to are:

- Transnet National Ports Authority: import and export data for containers and bulk trade (per port, >10 years)
- Transnet Freight Rail: Rail moved container data (origin to destination, >10 years)
- Shipping lines: import and export volumes and some container types (60–70% sample, 5 years)
- SARS: import and export trade data. (Both port and border post, >3 years)
- Industry body trade reports and forecasts
- Economist import and export freight history (tonnages, >10 years history)
- Economist import and export freight forecasts (tonnages, 30-year forecast, three scenarios)

In most cases these datasets provided a complete picture and no sampling decisions had to be made. However, for the shipping lines a Pareto principle was done to obtain a significant sample size. The shipping line sample was obtained by collecting datasets from the major shipping lines on a voluntary basis in exchange for a summarised high level feedback of the complete sample to only the contributors. This sample size was grown over a five-year period to the point where over 80% of all quay wall container contents were known. The same Pareto approach was followed with economist and industry datasets. The importance based on biggest volume and value was considered to create a list of commodity groups to focus on.

The datasets was analysed using Excel, SAS and Tableau as analysis tools. The investigation focus was on:

- Ports: focus on the major South African container ports, but also smaller ones.
- Commodity groupings: HS codes of various levels is used to translate shipping line commodity data to SIC codes and then combine the data with Transnet National Port Authority and Transnet Freight Rail commodity codes.
- Container physical types: 20 foot and 40 foot split is available for some of the datasets, others have more detail on type used, i.e. refrigerated, etc.
- Empty containers (in and out per port).
- Transhipment containers (in and out per port).

Trends and patterns were analysed to understand the historic average weight per container per commodity, and the physical container types used per commodity. Specific commodity and container type preferences per port have been investigated and linked to industry presence close to ports or in the port hinterland. Deductions were made as to who possible freight owners were. From this knowledge target companies and individuals for the primary qualitative research were identified.

1.9.2 Primary quantitative data

The survey targeting freight owners, LSPs and other involved industries was only designed once the secondary quantitative datasets were analysed. The aim of the survey was to enrich the datasets with further quantitative data. The survey obtained information about broad categories of supply chain decisions made by freight owners and LSPs that influence quay wall container movements. An inductive generalisation approach was followed to understand the present situation and the container users' outlook for the next 10 years. The design was such that the results either confirmed the analysis results from the quantitative datasets or provided new inputs for the modelling frameworks.

From the survey results, patterns and trends could be identified as inputs for focus group discussions. The details of the survey design are discussed in Chapter 6.

1.9.3 Primary qualitative data

Focus groups were held with key industry stakeholders at Durban and Rosslyn. Focus groups in these areas have been held to debate the patterns and trends identified during the survey analysis.

Primary data outcomes were used to identify participants for these focus groups. Typically this included freight owners, LSPs, importers and other industry participants who played a key role in industries that primarily use quay wall containers as a trade medium. The focus groups were scheduled to accommodate different sectors of the economy in different locations that have unique requirements for containerisation, i.e. refrigerated versus non-refrigerated containers.

Not all users of quay wall containers could be accommodated within this project scope. Thus the focus was on validating and refining aspects from the quantitative research that was still unclear at that stage. Due to the mixed-methods design, the sample for qualitative data collection need not be a representative sample of the industry. Only a representative sample of the aspects that need to be refined or explored further would be required in this retroductive reasoning approach.

Detailed notes were made at the focus groups by three separate individuals. The researcher used ATLAS.ti for the analysis and found it invaluable to find linkages between outcomes from primary data analysis and comments in various forms of qualitative data collected.

1.9.4 A Pareto process of elimination

The data collection and analysis for this study basically had three steps: secondary datasets, a survey and focus groups. A Pareto process was followed throughout where the biggest objects related to input parameters were investigated and once clarity was achieved, it was validated by the next step, and if validated, it was excluded from the next step. The researcher envisaged that it might be needed to follow up the focus groups with more focus groups or interviews if needed; however, the output and depth achieved through the three steps were deemed sufficient for the objectives to be achieved in this study.

1.9.5 Data limitations and potential sources of error

The secondary datasets obtained from industry were captured and refined over a period of several years. This means that the research team (in this case) became part of the data capturing and extraction process to the extent that they could influence and improve the quality of the data received in subsequent years. Irregularities and anomalies were frequently identified and highlighted. Discussions with the data providers then led to higher levels of detail and/or less anomalies in future datasets.

The datasets mostly represented a complete sample of the total country, industry or a region, or any combination of these. Through this, cross-verification possibilities between the datasets assisted in finding and eliminating potential errors, e.g. the total imported volumes declared for a commodity by the shipping lines, the exporters and the industry body need to align. If not, then investigations can be done to declare the discrepancies and resolve data issues.

The survey was sent to a wide audience, but the sample size of the respondents might be questioned. A larger response would have been preferred. However, since this was not the primary data input but served as confirmation under the mixed-methods design, it was deemed acceptable for designing the modelling framework parameters. A similar comment can be made for the focus groups where more locations and industries could have been included. However, the focus groups did not introduce any new modelling parameters, only deeper insight into the medium- to long-term influencers and industry behaviours to be expected. For both these modelling aspects port planners need to perform frequent follow-up work to confirm short- and medium-term input parameter values and medium- to long-term impacts of the influencers.

1.10 Structure of the document

The dissertation is structured as follows:

In Chapter 1, the background of infrastructure planning in the global shipping industry and in South Africa has been explained to highlight the research problem and objectives. Current container port capacity planning is done using aggregate methods with too little detail and definition in the modelling design. Chapter 1 also explains the research approach and methodology followed to achieve the research objectives utilising secondary and primary data.

In Chapter 2 various research concepts and definitions were tabled to make sure that the reader understands what they mean in the context of this dissertation. The method of commodity classification according to the SIC system is discussed to ensure that the content-based approach followed is based on a sound commodity classification.

In Chapter 3, relevant prior research is discussed and analysed to determine the methods and modelling parameters used by academics and practitioners to forecast container volumes to date. Various challenges and success stories are described to inform the research design.

Chapter 4 provides information on the broader context of influencers that have an impact on global trade, global shipping, port networks, and thus eventually on container volumes that will be transported around the world and over South African quay walls.

In Chapter 5 the outcomes of the historic container data analysis are described. Secondary data were collected from shipping lines, TNPA, TFR and SARS. This data was analysed and key learnings described in detail. The purpose is to determine the content of current shipping containers, and derive the decisions freight owners and Logistics Service Providers (LSPs) have made to create this history. Elements like the historic commodity content of containers, weight per container per commodity, preferred container types per commodity are described and important outcomes argued.

In Chapter 6 the methods to collect and analyse primary data through a survey and focus groups are explained. This combined quantitative and qualitative primary data collection and was utilised to strengthen and further inform the arguments created during the secondary quantitative data analysis.

Chapter 7 was a short chapter with the sole purpose of consolidating all the design requirements identified from the research input in Chapters 2 through 6.

After the primary and secondary data were described and consolidated, the learnings were linked to the methods and parameters from the literature review. This synthesis step followed in Chapter 8 where the proposed modelling technique and parameters were formulated. A confidence index was developed and included to illustrate the level of detail that was available on each aspect of the developed content-based quay wall container model.

Chapter 9 served as a verification and validation of the design requirements and the modelling parameters. The input parameters and models were applied to test them for appropriateness in the validation process.

Chapter 10 serves as conclusion to the dissertation. A critical view is taken on the methodology followed, the achievements on the developed parameters is taken to consider whether the modelling framework can be used or at what level it should be implemented by South African container port planners. Recommendations will be made as to the modelling framework that port infrastructure planners should include in their container forecasts.

2. Setting the scene: Research concepts and terminology definitions

First some basic terminology is discussed to explain what each means in the context of this dissertation.

2.1 Research concepts

2.1.1 Containers and maturity of the container concept

A container is intrinsically a package and transport medium and not a commodity. However containers manifest many characteristics of commodities from a freight demand and capacity perspective. A container could have various forms, shapes and sizes, in order to accommodate the unique commodity, freight owner preferences, transport mode and economies of scale. The most well-known container is the ISO standard deep-sea shipping container used extensively for international trade. These containers are all built to the same exterior lengths and widths to allow for easy stacking and transfer between modes.

The current 20 foot and 40 foot container sizes are deeply ingrained in the global shipping infrastructure landscape. The primary reasons for standardisation of containers in the 1950s were to enable standardisation of infrastructure for transportation and handling. In 1961, the International Organization for Standardization (ISO) set standard sizes for all containers, which enabled economies of scale for freight transportation globally (World Shipping, 2017).

Even though ISO containers offer a unitised standard, there are a number of physical types to consider that may further impact on demand and capacity planning. Many websites (Trade Risk Guaranty, 2017; Marine Insight, 2017; Container Auction, 2017) describe different container types, some specifying anything up to 16 different container types. Most of these are defined by any one of a combination of the following criteria:

- Size: standard length of 20 foot (6.09 m) or 40 foot (12.18 m)
- Size: Standard height (2.38 m) or high cube (2.69 m)
- Non-conventional containers that deviate from the above as follows: reefer, over-sized, open top, flat rack, collapsible, tanktainers, open side storage, tunnel, insulated, half height, car carrier.

Perishable items are shipped in reefer containers to maintain the temperature and humidity. Open top containers are used for easy loading of heavy and bulky cargo such as logs, bulk bags, machinery and odd-sized goods. Flat racks can be used for machinery, vehicles, boats or industrial type equipment. Open side containers are often used for palletised freight. Tank containers transport many types of bulk liquids such as beverages, industrial chemicals, fertilisers and vegetable oils.

These attributes can combine in a multitude of container options. About two-thirds of all containers are estimated to be forty foot containers (Budget Shipping Containers, 2017). Despite all the above options, according to Drewry Maritime Research, about 93% of all containers in circulation are standard twenty or forty foot dry containers. Refrigerated versions of these standard containers make up about 6%, tankers less than 1%, and non-conventional also contribute less than 1% of all containers in circulation globally (World Shipping, 2017).

The various container types and sizes require different ship, port-side, and distribution infrastructure. It is important for port infrastructure planners to understand the medium- to long-term requirements for both the quantity and type of container movements well in advance to facilitate planning and sufficient lead time for infrastructure investments. Detailed knowledge of medium-term requirements facilitates port planners' decision-making in terms of the location, timing, type and extent of additional container capacity required.

Transnet port infrastructure planners indicated during discussions that they would prefer to plan for a breakdown of container types by using the following physical types:

- Normal Twenty Foot Unit (NTFU)
- Normal Forty Foot Unit (NFFU)
- Normal High cube Forty Foot Unit (HFFU)
- Open Top Twenty Foot Unit (OTFU)
- Irregular sized Twenty Foot Unit (ITFU)
- Tanktainer (twenty foot) (TANK)
- Flexitank (twenty foot) (FANK)
- Reefer Twenty Foot Unit (RTFU)
- Reefer Forty Foot Unit (RFFU)

These are also the physical types used by Drewry and other international shipping authorities in their planning and reporting of the global container population. Although the worldwide trend is to move more to forty foot high cube containers, the nature of many commodities traded in and out of South African ports still prefer or dictate twenty foot containers to be used frequently.

The exact number of containers in circulation worldwide is difficult to find out and records vary significantly. Drewry reported 32.9 million TEUs in their latest published report in 2012 (World Shipping, 2017). Their annual container census is not publicly available. Another estimate from a British shipping company shows it to be around 23 million containers or 38.5 million TEUs in March 2016 (Budget Shipping Containers, 2017). How many are in circulation is maybe not that important, but from a port infrastructure planning perspective, it is important to know how many to expect over the quay wall per year, and the size of the ships that they arrive and leave on. This will dictate the required port infrastructure.

Other container sizes available are 45-foot (13.7 m), 48-foot (14.6 m), and 53-foot (16.15 m) (World Shipping, 2017)). In the USA and parts of Europe specific domestic containers are utilised. The USA 53-foot container is used to such an extent that its volumes in the USA have passed the volumes of ISO containers used domestically in the USA (Rodrigue & Slack, 2017). In Europe unique domestic containers with drop sides, to facilitate pallets being loaded from the sides, are used widely (Internationaional Union of Railways (UIC), 2012).

A unique container for Southern African conditions and thus domestic only use might be an option. The challenge would be to come to a decision on what this standard for domestic containers should be that satisfy all related parties’ transport requirements and economies of scale.

Proper loading of unique containers for exporting is important to ensure the stability of the ships, trucks and trains that transport these containers. It is also important for the container’s structure itself. A number of incidents along with security issues have led to a number of international policy and regulations changes in the last decade. The World Shipping Council (WSC) and the International Chamber of Shipping (ICS) developed a training guide to educate freight owners on the correct loading of single containers. This document, *Transport of Containers by Sea - Industry Guidance for Shippers and Container Stuffers*, was published in 2008 (World Shipping, 2017).

In 2010 the WSC and the ICS requested the International Maritime Organisation (IMO) to review their policy regarding the declaration of containers for deep-sea shipping. In May 2014, the IMO's Maritime Safety Committee (MSC) approved changes to the Safety of Life at Sea (SOLAS) convention regarding a mandatory container weight verification requirement on shippers. This change is applicable to *Dangerous Goods, Solid Cargo and Containers (DSC)*. This change will impact container shipments due to its requirement for verification of container weights before being placed aboard ships. The requirement became legally binding on 1 July 2016 (World Shipping, 2017).

2.1.2 Intermodal transport

Intermodal transport is the use of two or more modes of transport for the seamless movement of goods in the same loading unit.

The standard shipping container is the pivotal loading unit that enables global and domestic intermodal transport. The other critical success factor in intermodal transport is the optimisation and efficacy of transfer points (such as ports and inland terminals) within the network. A higher requirement for intermodal transport solutions would increase port container volumes at a faster rate than trade growth.

Discussions relating to containers are often focused on the intermodal nature of international maritime trade – limiting the discussion to ISO container sizes and port container terminals. In actual fact, the domestic use of containers for inland transportation has outstripped the use of import/export containers in the USA while in Europe domestic container movements are the largest growing rail sector. The three applications of containers present in national supply chain systems are:

- Containers that cross the quay wall. This mainly deals with import/export and transhipment movements and issues relating to container ship and port capacity, as well as the capacity and efficiency of port handling equipment and operations come into play;
- The hinterland movement of containers that crossed the quay wall. In South Africa this primarily deals with road and rail transport and issues relating to the capacity and efficiency of the modal interfaces (port/rail, port/road, and road/rail);
- Purely domestic container movements. In South Africa this refers only to road and rail transport and the capacities and efficiencies of the road/rail interfaces (i.e. intermodal terminals).

For the purposes of this dissertation, the focus is on ‘containers that cross the quay wall’.

2.1.3 Functional typologies related to container transport

Functional typology is a modelling term that will be used to describe the impact a container shipment has on freight surface and quay wall planning. Any container shipment might influence one or more of the functional typologies listed below:

- Marine (deep-sea)
- Marine (coastal)
- Domestic
- Empty repositioning (marine)
- Empty repositioning (land-based)
- Natural transhipments (associated with gateway volumes)
- Targeted transhipments (as part of a port-hub strategy)

These functional typologies are shown in graphical format in Figure 2.1 to explain their unique nature. Two typologies for empty repositioning and transhipments are combined in one graphic each. Due to the complexity, impact, extent and influence of each of these models on different infrastructure requirements, separate modelling frameworks could be proposed for each of them. This complexity is beyond the scope of a single dissertation, and thus scope limitation is required to ensure that each of them will be defined properly.

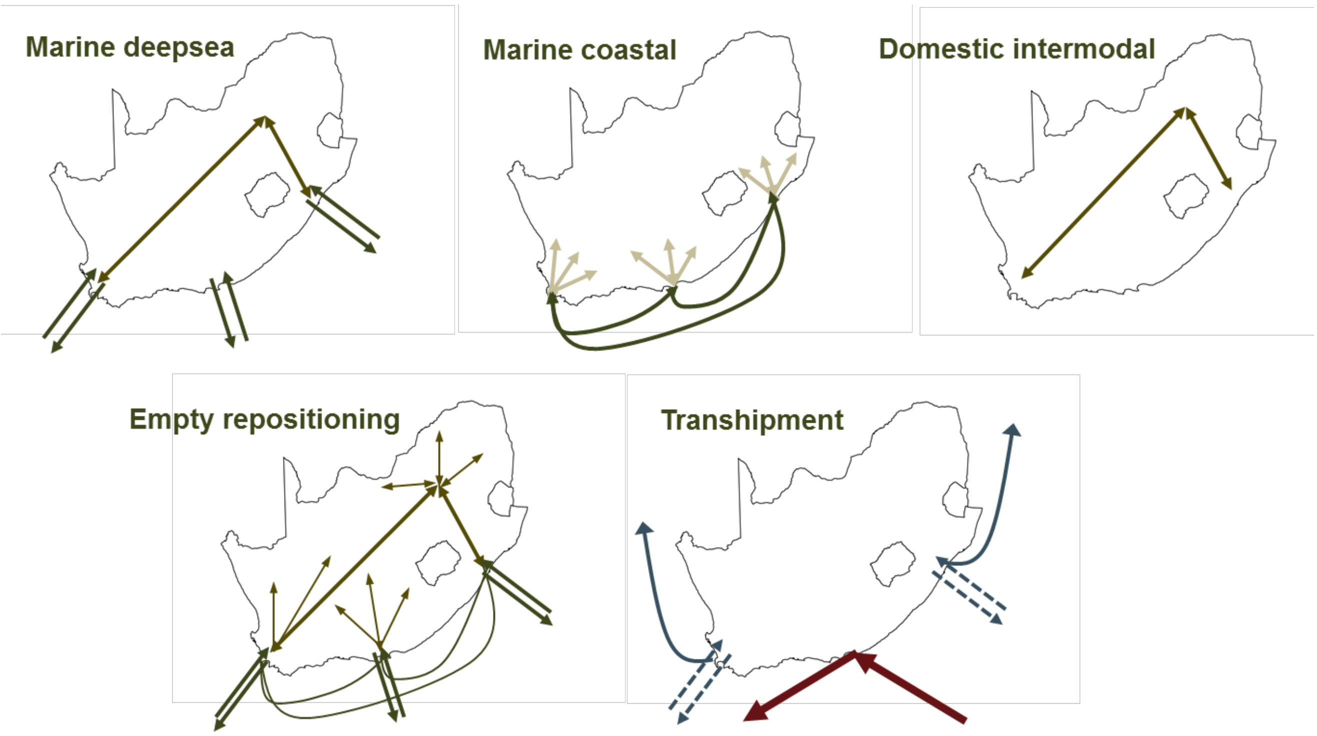

Figure 2.1: Functional typologies related to container transport explained graphically in the South African context

These functional container typologies can influence the quay wall movement or not, but most of them form part of any quay wall planning and demand forecasts. Not all container forecasts behave the same and different demand drivers are at work depending on the functional typology and the 'markets' being served. A commodity that needs to be transported from A to B might have to utilise several modes of transport in order to get to its final destination. Along the route this commodity will share ships, barges, trains, trucks, aeroplanes, pallets, and shopping trolleys with many other commodities to achieve the economies of scale for each leg of the logistics chain. The route followed and the modes used might not always be optimal for the one commodity, but sharing costs with other commodities will achieve economies of scale that benefit all the sharing commodities.

Since a thorough understanding of the operational implications and decisions that drive the choice of functional typology will enhance accurate planning, a few of these are described briefly:

- A reefer container of oranges exported from Citrusdal to New York will use the Marine (deep-sea) typology from the Cape Town port.
- The cardboard boxes used to pack these oranges in are manufactured in Durban. The farm might utilise either the Domestic or the Marine (Coastal) typology to transport the boxes from Durban to Citrusdal directly or via the Port of Cape Town respectively.
- The neighbouring container of oranges on the same deep-sea ship from the Port of Cape Town to New York might be shipped from New York to Boston for a different consumer market there. This is due to no direct shipping route between the Port of Cape Town and Boston being available with the contracted shipping line, thus using the Natural Transhipments typology in New York.

- Another container of oranges from the same farm might utilise the Marine (Deep-sea) typology to Singapore, and from there be Transhipped (port-hub strategy) to various final destinations across the Far East. The shipping line strategy in such a case would be to have regular ships between Cape Town and Singapore and also between Singapore and the various locations across the Far East. It would not make economic sense for this shipping line to have regular ships between Cape Town and each of the various ports in the Far East.
- At the start of the orange picking season, the reefer containers used for the above shipments need to be available in Cape Town or Citrusdal. If not enough refrigerated products are imported to Cape Town and surrounding areas, a repositioning of empty reefer containers is required. This could be done from land-based empty container depots or via marine from other areas.

Careful planning needs to be done to provide the correct infrastructure supporting the logistics operational requirements of businesses in South Africa. Both transport and terminal facilities need to provide sufficient infrastructure of the required capacity and type to facilitate the economic movement of commodities from source to destination.

For the purposes of the container forecast in this dissertation, the focus is on:

- Marine (deep-sea)
- Transhipments (natural and targeted combined)
- Empty repositioning (marine only)

2.1.4 Freight Demand Model (FDM)

South Africa's Freight Demand Model (FDM) is the source of the commodity-based flow data used in this dissertation. The FDM is South Africa's national surface freight transport demand model based on a national Input-Output model of the economy. The FDM estimates total supply and demand of commodities in predefined geographical areas. To explain the FDM a number of attributes of the model are briefly explained:

- 372 geographic districts: The model's data is disaggregated to 356 districts, 7 ports, 1 airport and 8 border posts;
- Commodities: The inputs and outputs are divided into 83 commodity groupings;
- Economic input elements: Each district has economic input elements per commodity for: production, intermediate consumption, final consumption, imports, exports and investments. Economists derive these values through a balanced econometric input-output model;
- Origin-Destinations pairs (OD pairs): Freight can move between any of the 372 districts identified above (as relevant per commodity), thus potential combinations of almost 70 000 OD pairs;
- Freight flows: A gravity modelling approach is followed to distribute freight from supply to demand per commodity;
- Modal split: Actual rail flows are received from the incumbent (Transnet Freight Rail), modal split analysis between road and rail is therefore enabled;
- Forecast and scenarios: The economists provide a 30-year forecast at 5-year intervals for three scenarios: low, high and likely growth scenarios.

The methodology has been applied annually since 2006 (Havenga, 2013). The complexity and subsequent vast amount of data lines that are generated in this model does create challenges. The data is managed in SAS, but often the outputs are viewed by developers and users in Excel. In 2006, the Excel limit for lines on a data sheet of 65 536 lines was overshot. Newer versions of Excel helped, but due to added complexity by 2012 the extended Excel data limit of 1 048 576 lines was also reached.

An important aspect to mention at this stage is that the national input-output model is a key input to the FDM and thus to the proposed container modelling; however, it is not one of the industry datasets to be analysed later in this dissertation. The modelling parameters developed in this dissertation should rather be applied to the quay wall freight movements in the national input-output model of the economy and thus be translated to container demand. The outputs of the detailed shipping line data analysis presented in this chapter would however be an invaluable input into the national input-output model for future years.

The container model proposed in this dissertation is an extension to the FDM described above, and will thus use the complete dataset of the FDM as inputs.

The FDM is a valuable input to the Transnet 30-year long-term planning framework (LTPF). It informs the Transnet seven-year corporate plans and acts as a baseline for their long-term infrastructure planning.

2.1.5 Modelling parameter

A parameter is defined as '*any factor that defines a system and determines (or limits) its performance*' (Free Dictionary, 2016). The input parameters identified in this dissertation would be modelling factors combined with factors influencing the container trade volumes and that need to be considered when modelling and planning for future container volumes. The complete system and its performance need to be described by the parameters chosen. A large number of parameters might be required to fully define the system mentioned above. One of the dissertation outcomes would be to identify all the relevant parameters to be considered in building an accurate container forecasting model.

2.1.6 Forecast horizon

The forecast horizon typically considered for port infrastructure planning could have different time durations depending on the intended use. The forecast years that port planners from Transnet Group Planning use have the following years included:

- Base/reference year (first calendar year with complete historic data available)
- Year 1 (Base +1 = current calendar year)
- Year 2, 3, 4, 5, 6 (Base + x; short-term forecast years)
- Year 11 (Base +11 = 10-year medium-term forecast)
- Year 16 (Base +16 = 15-year long-term forecast)
- Year 31 (Base +31 = 30-year very long-term forecast)

The user requirements from the port planners have different goals over the complete time horizon. Short-term plans are related to marketing goals for business divisions to target freight for rail, pipeline and port services. Medium-term horizon outputs are important for initiating and planning specific large-scale infrastructure capacity expansion projects to be completed in time for the validated demands. Long- and very long-term forecasts provide valuable insight into the dynamics of long-term strategic infrastructure planning on a national scale.

2.1.7 Other definitions

Economic activity, as mentioned in the dissertation title, refers to business events that requires the movement of goods between economic partners. Thus, economic trade activity would impact full containers across the quay wall between local and international partners. In the context of this dissertation, the concept is used in its wide definition to highlight the importance of the contents of full containers versus the container used blind to its content.

Ships are vessels of a considerable size fit for deep-water navigation that could be used to move freight between ports in different countries or continents. Ships are mostly equipped to transport specific freight types, i.e. containers, liquids, bulk freight, etc.

Pendulum routes in shipping characterise containerised cargo ships with a regular itinerary between sequences of ports electing to service ports having important trade relations.

Ports are the term referred to in the shipping industry that denotes a harbour with piers or docks that can accommodate ships of various shapes and sizes. Port services include berthing, loading and offloading freight, customs clearance, ship service and repair facilities, etc. Ports also integrate the deep-water transportation with inland and other deep-water transportation through handling and storage of freight between modes (US Department of Transportation, 2008).

Terminals are assigned areas where containers (and other freight) are staged in preparation for loading onto a ship or other transport mode (Pienaar & Vogt, 2016). Or the same applies to containers after being offloaded from a ship or transport mode before they are moved to their final destination. Terminals also host quayside equipment which needs to be specific to the commodity loaded or offloaded at the terminal and need to be able to accommodate the visiting ship's dimensions.

Terminal operators have the responsibility to handle freight and containers and are essentially the link between one transport mode and the next (US Department of Transportation, 2008). All ports in South Africa are operated by one operator, i.e. Transnet. This has benefits and disadvantages from international alternatives where several terminal operators can manage different terminals in a single port. The details of this configuration in South Africa are beyond the scope of this dissertation; refer to Havenga et al. (2017) for more detail.

Bulk freight for this dissertation includes all freight that is handled in large volumes and not in containers. These freight commodities are often transported by dedicated ships suitable for handling the specific commodities. Bulk freight includes items classified as dry bulk (i.e. coal, iron ore and manganese in South Africa), liquid bulk (i.e. fuel, crude oil) and break-bulk (i.e. rice in 1-ton bags or large-sized equipment).

2.2 Commodity classification systems

At the centre of this dissertation is the notion of the importance of container content. A thorough breakdown of the transportable economy into commodity groups is required that can be utilised to understand and forecast the contents of containers. This breakdown needs to be done within the larger picture of freight movement within the South African trade context. Commodity classification systems and the definition requirements from role players are investigated in this section.

2.2.1 Economist classification systems

Commodity classification is the cornerstone of freight-flow analysis and the resulting understanding of what is inside containers. Economists have used disaggregated econometric models to explain economic behaviour for decades. They would, for example, have mining production of coal and iron ore as outputs by that sector. This would be linked to consumption of these commodities together with other inputs to produce steel as a manufacturing output, which is consumed in the construction sector. To establish these econometric models, classification systems are needed to decide which commodities belongs to which groups and to create a consistency between various economists' models. This ensures that comparisons can be made between models and interaction is possible. This also enables public sector departments to capture actual information in a classification system that is transparent, consistent and repeatable.

Over the last century entities from various regions developed their own systems in isolation. Internationally it has been a challenge to agree on the same coding and categorisation used for these classification systems. Especially with globalisation and the advance of information systems more recently it has become more and more important to have the same classification system as your trade partners. This would ensure that your customs officials do not have difficulty in understanding the content of imported and exported materials, and that tariffs are applied consistently, fairly and even automatically. Table 2.1 provides a selection of the vast number of industry classification systems found, with information about the sponsor who developed it, their criteria for developing it, the level of detail and digits used, and the revisions and or date it was issued.

Table 2.1: An illustration of some of the industry classification systems used (Wikipedia, 2017)

Abbreviation	Full name	Sponsor	Criterion/ Unit	Node count by level	Issued
BEC	Classification by Broad Economic Categories	UNSD, Economic Statistics and Classifications Section	End-use category of transportable good	Category (N:7 one-digit), Sub-categories (N: 2-digit and 3-digit)	1971, Rev 1 in 1976, Rev 2 in 1986, Rev 3 in 1988
ISIC	International Standard Industrial Classification of All Economic Activities	United Nations Statistics Division	production/ establishment	4 digits 21/88/238/419	1948–present (Rev. 4, 2008)
NAICS	North American Industry Classification System	Statistical bureaus of US, Canada, and Mexico	production/ establishment	6 digits 17/99/313/724/117 5 /19745	1997, 2002, (2012)
NACE	Statistical Classification of Economic Activities in the European Community	European Community	production/ establishment	6 digits	
SIC	Standard Industrial Classification	US	production/ establishment	4 digits 1004 categories	1937–1987 (superseded by NAICS, but still used in some applications)
ICB	Industry Classification Benchmark	FTSE	market/ company	10/20/41/114	
GICS	Global Industry Classification Standard	Standard & Poor's, Morgan Stanley Capital International	market/ company	2-8 digits 10/24/68/154	
TRBC	Thomson Reuters Business Classification	Thomson Reuters	market/ company	10/25/52/124	
UNSPSC	United Nations Standard Products and Services Code	United Nations	Product	8 digits (optional 9th)	1998 – present

Some of these were developed by global organisations like the UN, or trade blocks like NATO or the EU. Others were developed by country statistics divisions like USA or the UK. Some were developed by and/or for companies like Standard & Poor's GICS and the FTSE's ICB. For some of these the focus is international trade or industry specific, while for others a specific company's view or a purely product criteria was the focus. Some of the most relevant to this dissertation will be discussed in further detail in the remainder of this section.

2.2.1.1 Broad Economic Categories (BEC)

The United Nations Statistical Division (UNSD) (Classification by Broad Economic Categories, Defined in terms of SITC, Rev.3, (BEC Rev.3), 2017) defines their classification by Broad Economic Categories (BEC).

This was derived from their Standard International Trade Classification (SITC) coding system and released the third revision in 1988. The purpose of this classification was to categorise trade statistics into large economic classes of commodities. The purpose of the BEC was to provide a summary tool for transportable goods planning with the detail still based on the SITC. This list has seven level 1 and fourteen level 2 codes, which provide a sufficient reporting level, but is not sufficient for planning and forecasting. Although this list focuses primarily on transportable goods, more detail would be required on various levels to plan for unique commodities. This list provides very little detail on agricultural products or on mining outputs, but mixes these high level economic divisions into single elements of, for example, primary and processed foods and beverages. This tends to be problematic when attempting to forecast these mixed commodities, such as sugar cane and processed sugar.

2.2.1.2 Standard International Trade Classification (SITC)

The Standard International Trade Classification (SITC) is also developed and published by the United Nations Statistics Division (UN Statistics Division, 2017). Revision 4 of the SITC divides the complete economic set of trade activities into a top level breakdown of eleven commodity groups without a clear distinction between the primary and secondary divisions. The purpose of this view was purely from a trade classification perspective and the division of elements has a strong item trade value focus.

2.2.1.3 The International Standard Industrial Classification (ISIC)

The International Standard Industrial Classification (ISIC) is also developed and published by the United Nations Statistics Division. The purpose for ISIC was purely from an econometric planning and reporting perspective. Thus the division has a strong economic input-output focus. Revision 4 (UN Statistics Division, 2017) of the ISIC divides the complete economic set of activities into a top-level breakdown of 21 economic sectors, of which three form part of the transportable economy. Although this level provides much more detail, it still does not provide sufficient granularity for planning purposes. For example, although manufacturing is broken down into various subgroups, one category for all agricultural production outputs provides too little detail. The same can be said for the five categories for mining products. The category *B-07 – Mining of metal ores* would be dominated by Iron Ore mining in South Africa. Planning and forecasting for this commodity needs to be on a deeper level of granularity. Even adding the third level of detail would still not provide sufficient subcategories for chrome, copper, manganese, titanium, etc. for the South African transport modelling environment.

This top-level breakdown is completely different from the one shown in the BEC and SITC in the previous subsections. All three were developed by the UN, for different purposes, but can create significant confusion if not made clear as to which one is used in which scenario.

The UN also developed a purely product focused classification system called the United Nations Standard Products and Services Code (UNSPSC) that is a classification used especially for eCommerce (UN, 2014).

2.2.1.4 World Customs Organisation: HS codes

The World Customs Organisation (WCO) has developed the Harmonised System (HS). The HS is used by over 200 countries. It is used by customs authorities, statistical agencies, government regulatory bodies, international organisations and the private sector. The WCO has the responsibility to ensure the integrity and relevance of the HS. In pursuit of this, the newest HS code nomenclature entered the scene on 1 January 2017 with 242 amendments (WCO, 2017)

The HS is used to monitor and control the import and export of commodities through:

- Customs tariffs

- Collection of international trade statistics
- Transport tariffs and statistics
- Rules of origin
- Trade negotiations (e.g., the World Trade Organization schedules of tariff concessions)
- Monitoring of controlled goods (e.g., wastes, narcotics, chemical weapons, endangered species)
- Areas of Customs controls and procedures, including risk assessment, information technology and compliance.

According to the WCO (2017) the HS is a universal economic language and code and an indispensable tool for international trade. They deem that over 98% of all international traded merchandise is classified in some way according to the HS. The HS is made up from approximately 5 000 commodity groups, by using a six-digit coding system. These codes are arranged in a logical and legal structure with well-defined rules to ensure uniformity of classification. An example of the six-digit coding system is shown in Figure 2.2. Every two digits relate back to a level of classification, i.e. in Figure 2.2 the code 1006.30 is built up as follows: the '10' relates to all cereals, the '06' relates to Rice, and the '30' to the specific presentation of this item.

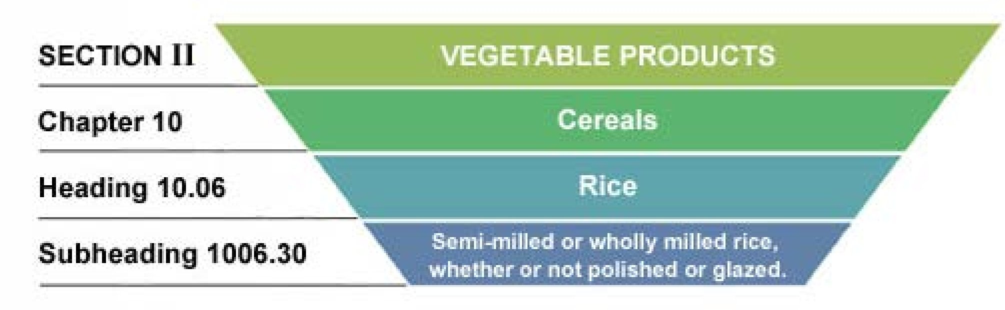

Figure 2.2: An example of the six-digit HS coding system (Unknown, 2017)

The HS contributes to the synchronisation of trade procedures and the customs procedures around non-documentary trade data interchange. It thus helps to reduce the cost of trade by facilitating the ease of trade and customs inspection. It is also used by governments and international organisations for:

- Internal taxes,
- Trade policies,
- Monitoring of controlled goods,
- Rules of origin,
- Freight tariffs,
- Transport statistics,
- Price monitoring,
- Quota controls,
- Compilation of national accounts,
- Economic research and analysis.

It is especially this last bullet that makes the HS relevant for this dissertation, together with the bullet on *Transport statistics*. The HS provides a unified coding system that assists in synchronising the various datasets available on a detailed commodity level. Many of the datasets are only available in a format that can be translated to the HS code, and then to the SIC coding system. The HS system thus often acts as an intermediary classification system that makes it easier to translate to a usable format. This ensures that container content can be classified and forecasting models built that interact and integrate with other models and datasets from various parties.

2.2.2 Standard Industrial Classifications used in South Africa

Statistics South Africa is the custodian of various datasets in South Africa. Their mandate includes capturing and maintaining data on the themes of people, economy, living conditions and the natural environment. (Statistics South Africa, 2017). Among these economic datasets is the Standard Industrial Classification (SIC) coding system for South African agencies (SARS, 2017). SARS also uses the SIC, with its major divisions shown in Table 2.2. The SIC is a classification of economic activities of industries based upon the International Standard Industrial Classification (ISIC) of all economic activities. The classification provides a standardised framework for the collection, tabulation, analysis and presentation of economic data. Adherence to the SIC promotes uniformity and comparability of data compiled from different sources.

The transportable sections applicable to this dissertation are the first three categories, i.e. agriculture, forestry and fishing; mining and quarrying; and manufacturing. Details on the subsections of these three divisions can be found on the Statistics South Africa website (Statistics South Africa, 2017). The other high level divisions from 35 through 99 all contribute to the South African GDP, but these outputs require a limited impact from transport, if at all. That is, electricity requires coal, as a mining output that needs to be transported to the coal power station, but electricity as an output does not require transport. Similar arguments can be followed for the rest of the list following manufacturing.

Table 2.2: South African SIC codes used by SARS (SARS, 2017)

Corresponding Division Code	Description
01-03	Agriculture, forestry and fishing
05-09	Mining and quarrying
10-33	Manufacturing
35	Electricity, gas, steam and air conditioning supply
36-39	Water supply; sewerage, waste management and remediation activities
41-43	Construction
45-47	Wholesale and retail trade; repair of motor vehicles and motorcycles
49-53	Transportation and storage
55-56	Accommodation and food service activities
58-63	Information and communication
64-66	Financial and insurance activities
68	Real estate activities
69-75	Professional, scientific and technical activities
77-82	Administrative and support service activities
84	Public administration and defence; compulsory social security
85	Education
86-88	Human health and social work activities
90-93	Arts, entertainment and recreation
94-96	Other service activities
97-98	Activities of households as employers; undifferentiated goods-and-service-producing activities of households for own use
99	Activities of extraterritorial organisations and bodies, not economically active people, unemployed people etc.

Havenga (2007) explained the dilemma transport modellers have in this regard. Economic clusters used by economic and government institutions do not cater with sufficient detail on the transportable sectors. For Transnet Freight Rail, the two major commodities by volume are coal and iron ore exports. This contributes more than half of all tonnes transported by TFR and exported by TNPA. Havenga (2007) explains how this led many of the logistics-related entities to develop their own classification systems to provide them with sufficient planning level detail. The outcome was distinct and incomparable classification systems fitting their individual objectives. However the incompatibility creates challenges for integration and communication between these systems.

2.2.3 Commodity classification used in South Africa's freight demand model

2.2.3.1 Introduction

The original commodity classification used in the FDM was developed in 1995 when the first concept FDM was developed. The commodity classification system was necessary because:

- TFR, at that stage, had more than 1 000 commodities on their business system.
- The TFR commodities did not match any economic forecasting or classification system, which meant that external information sources could not be used to derive freight flows, devise forecasts, or validate any of the results obtained.

The 1995 FDM commodity classification was based on the SIC. The FDM, however, considered specific requirements relating to the transportable economy. This means that both the primary sector (mining and agriculture) and secondary sector (manufacturing) were disaggregated in more detail than typically utilised in macroeconomic forecasting models. From a typical macroeconomic perspective, economic sectors are typically disaggregated based on **value**, which means that only a limited number of e.g. mining commodities are reported on in detail (often only gold and diamonds, and sometimes coal and iron ore given their bulk status). For instance one single manufacturing sector's demand, automotive, only equals 0.6% of coal mining by weight, but 40% of coal mining by value.

The primary focus of the model, at that stage, was to measure and forecast surface freight flows (i.e. road and rail), which means ports and their unique requirements received less attention. The FDM then had 93 commodities in total: 21 mining, 16 agricultural and 56 manufacturing commodities. Two principles emerged from the process (Havenga, 2007):

- A freight-flow commodity classification system should match a standard system in the economy, such as the SIC or HS systems, which is widely used in South Africa and internationally.
- A freight-flow commodity classification system should translate and link up to the sectors of relevance to the transportable economy.

For this dissertation, the specific South African commodity **volumes, values and movements** need to be analysed to ensure a breakdown is developed providing sufficient detail for these modelling elements:

- TNPA bulk port volumes
- TFR transported commodities
- Shipping line data for bulk and container movements
- SARS export and imported volumes for port and cross border movements.

2.2.3.2 Improvements in 2006 to 2009

The concept model of 1995 was redesigned and installed as part of the full-blown and repeatable Freight Demand Model (FDM) in 2006 (Havenga, 2007). Many of the initial classification issues could then be addressed with especially a large volume of completely unnecessary smaller (especially manufacturing) commodities removed. Clothing, for instance, was represented by five different commodities that split footwear, textiles, clothing, leather and leather substitutes and even included commodities such as jewellery. This detail was unnecessary from a transport significance perspective. The commodities were reduced to 62 in total, 16 mining, 17 agricultural and 29 manufacturing commodities. The principle that emerged from the process is:

- A freight-flow commodity classification system should aggregate 'smaller' commodities that could be grouped together with such low volumes that they will never play a significant role in the freight transport task on any mode. This creates information technology 'space' in that the forecasting databases stays manageable in size.

A few minor improvements happened in the years 2008 and 2009 adhering to this principle.

2.2.3.3 Improvements between 2010 and 2012

Improvements between 2010 and 2012 largely focused on expanding voluminous commodities into more segments to make it more useful for transport service providers on the one hand and increase forecast accuracy on the other hand. Key mining commodities were disaggregated in more detail due to the significant port and rail infrastructure requirements (such as coal, which constitutes a third of the economy by volume, was split into five sub-commodities, i.e. export, domestic, power station and Sasol coal and fly-ash).

Certain commodities, apart from being voluminous are also of strategic importance to the economy, of which fuel was an example. Fuel was split into seven commodities, i.e. crude, petroleum, aviation fuel, diesel and other petroleum products, methane rich gas and natural gas. Iron ore and manganese were also split into domestic and export commodities due to the major strategic investments required from Transnet and also the very different supply chains of these commodities’ domestic and export requirements. The 74 commodities in total by early 2013 constituted 17 agricultural, 24 mining and 33 manufacturing commodities. Three principles emerged from this process:

- Commodities with very large volumes lead to a high level of aggregation, making forecasts more difficult. Sasol and Eskom alone use one-fifth of South Africa’s economy by volume (and then only a portion of total coal mined) and have completely different forecast drivers. These forecast drivers can be established and used to forecast Sasol and Eskom coal demand separately.
- The supply chains of certain voluminous commodities differ completely for certain applications and the different applications or disaggregation that can be identified is significant (such as for export and domestic iron ore and manganese).
- Forecast accuracy is improved if larger commodities are split.

The FDM utilises the macroeconomic input-output (I-O) model of the economy as its platform. Increased accuracy in subcomponents of supply and demand data in the I-O model on commodity level improves the overall model due to the interdependencies between industries in terms of intermediate inputs implicit in the I-O model (Leontief, 1986).

2.2.3.4 Latest Improvements (2014)

The process followed for further refinements in 2014 was built on the same foundation as the principles highlighted above. What were, however, considered were not only volume, but also market share and the requirements from other operating divisions than TFR. A system was developed and followed up with consultations with Transnet Group Planning and all the operating divisions where some more proposals were received and incorporated.

Examples include a former commodity, *Titanium*, that contains Titanium slag, Rutile and Ilmenite, which all have significant volumes, but different supply chains and addressable market shares for road and rail transport and port preferences. Targeting market share is difficult if these are aggregated, but much more sensible if measured, targeted and reported separately.

There were also cases where commodities were reported as 'other' (constituting the remainder of a group where previous significant commodities were removed) such as *Other Non-Ferrous Metal Mining* (where non-ferrous metals such as copper were already removed). On closer inspection the research team realised that most of the 'other' were Alumina (98%) and by separating it the 'remainder' is significantly reduced and the Alumina can be sensibly targeted. Another example was *Chemicals and Fertilizer Minerals* of which 80% is Rock Phosphate (a significant Transnet rail and port commodity) and 15% Sulphur. The same was true for salt and zircon (significant for some of the operating divisions) that was broken out of other non-metallic mineral products.

Processed Foods also include many disparate types of foods. Special attention was needed for especially the staple parts of processed food that are usually voluminous and similar, making handling for rail and port operations relatively easier and targetable. Rice, potatoes and cassava were broken out of processed foods and listed as separate commodities.

The FDM is expanding in functionalities every year, and this creates information technology storage space and computing power issues as indicated in section 2.1.4. In order to adhere to the principle of not multiplying the complexity, some aggregations were also necessary. These included combining all of the 'machinery' products into a group, all the meat products in a group and also grouping plastics, glass and rubber (excluding automotive parts) together with other manufacturing. Finally a 'new' commodity was also created i.e. scrap, by removing all metal scrap from separate commodities and combining them. The supply chains of 'reverse logistics' differs so much from 'forward logistics' that this was necessary (Pienaar & Vogt, 2016).

The classification system now has a total of 83 commodities: 20 agricultural, 30 mining and 33 manufacturing commodities. Principles that emerged were to:

- Limit 'other' commodities to include only constituent parts that are small or have less significance for the operating divisions
- Limit 'other' commodities to small volumes or commodities that have an insignificant freight task for rail, ports or pipelines
- Consider the Transnet operating divisions’ (TNPA, TPT, TFR, TPL) requirements in the classification system
- Make sure that the classification system can be 'translated' into all of the operating divisions’ classification systems.

Many of these explanations are sourced from project documentation established over the years between Transnet Group Planning and the researchers. The commodity classification system in use in the FDM has changed dynamically over a decade to be more representative of what is needed for planning and forecasting of all the transportable sectors of the economy.

An important aspect to mention here is that the first analysis of shipping line datasets to be discussed was already included in the decision-making process about including and excluding commodities in this 2014 process. Thus some of the decisions and the principles identified originated from quay wall container content deemed of significant volume or of importance to port planning.

2.2.3.5 Summary of developments over the years

In summary, Table 2.3 indicates that there are now less commodities in the FDM than in 1995. The commodity classification system is more representative of all the transportable sectors of the economy.

Table 2.3: Progression of FDM commodity classification breakdown in numbers (% of total)

Year	Agriculture	Mining	Manufacturing	Total
1995	16 (17%)	21 (23%)	56 (60%)	**93**
2006	17 (27%)	16 (26%)	29 (47%)	**62**
2010	17 (23%)	24 (32%)	33 (45%)	**74**
2014	20 (24%)	30 (36%)	33 (40%)	**83**

2.2.4 Commodity classification for container modelling

TNPA uses approximately 500 different commodities to capture bulk freight shipments across the quay wall. These are consolidated into 98 commodity groupings for internal reporting purposes. However, they do not capture content detail of containers at all. SARS capture data according to approximately 7 300 tariff codes that are related to the Standard Industrial Classification (SIC) used by Statistics South Africa. Shipping lines capture a variety of commodity information for containers. This differs in level of detail received from them over time. Some shipping lines capture a vast amount of detail, others not. The total list of commodity descriptions classified over the 6-year data sample analysed in Chapter 5 for all the shipping lines exceeds 43 000 lines of data.

Most of these commodity classifications can be traced back to either the Standard Industrial Classification (SIC) system, or the Harmonised System (HS) developed by the World Customs Organisation (WCO, 2017) and used extensively by the maritime industry. All the datasets were linked back to the FDM commodity SIC code groupings. This was done by using translation tables relating detail level HS codes to detail level SIC codes. The commodity classification list has translation tables to all Transnet operating divisions, HS codes, SARS codes, Statistics South Africa’s SIC tables and shipping line commodity classifications (refer Appendix A).

Deviations from this set will only be due to one of the existing principles identified above being breached while analysing the newer container datasets, or if new principles are identified based on these new later shipping line datasets. In such cases a suggestion would be made from this dissertation to review the commodity classification through a similar inclusive process followed.

The next step is to identify which characteristics make certain commodities attractive for transport in containers, as discussed in the next section.

2.3 Identification of containerisable freight

Brown and Hatch (2002) assert that 'rail intermodal’s economic value and contribution to the economy resides primarily in long-haul corridors' and highlight typical freight, mostly fast-moving consumer goods (FMCG). These are products that are sold quickly and generally consumed on a regular basis, as opposed to durable goods such as kitchen appliances, which are replaced over a period of years. FMCG product categories comprise food and dairy products, pharmaceuticals, consumer electronics, packaged food products, household products, beverages, and the like.

According to Havenga et al. (2011), the key driver of freight transport density (impacting returns) is the unitisation of cargo. This requires a large storage footprint (e.g. the stacking of containers, and the palletisation of goods within containers). For the purposes transport from rail-friendly freight flows, the concept of ‘unitisation’ was therefore narrowed to ‘palletisation’ in order to ensure that only freight that can be easily packed on pallets and stacked in containers is identified. To identify freight that could be described as 'palletisable', Havenga et al. (2011) conducted three workshops with industry experts and the commodities from the freight flow model described above were classified into two groups, i.e. 'palletisable' and 'non-palletisable'. This classification is reflected in Table 2.4.

Table 2.4: Classification of palletisable versus non-palletisable final consumption products

Palletisable FMCG	Non-Palletisable FMCG
• Food & food processing • Beverages • Tobacco products • Pharmaceuticals & toiletries • Motor vehicle parts & accessories • Other chemicals • Non-metallic mineral products • Bricks • Non-ferrous metal basic industries • Machinery and equipment • Textiles & clothing • Printing and publishing • Other manufacturing industries • Rubber products	• Automotive • Electrical machinery • Furniture • Metal products excluding machinery • Transport equipment

2.4 Design requirements identified in this chapter

Several requirements as defined by Van Aken et al (2006) can be deduced from aspects covered in this chapter as shown in Table 2.5. The table provides the following detail columns:

- Unique *Requirement ID* to be carried through the dissertation;
- *Requirement description*;
- A brief *motivation* for the inclusion from the material covered in the chapter;
- *Quay wall extent* of the requirement to Marine deep-sea, Transhipped and/or Empty containers.

This table format will be repeated throughout Chapters 2 to 6 to list and motivate the design requirements identified in each chapter. The number of the Requirement ID's will be started in Table 2.5, continued in the subsequent tables, and summarised and further analysed in Chapter 7.

Table 2.5: Design requirements identified in Chapter 2

Req. ID	Requirement	Motivation	Quay wall extent
U1	Disaggregated commodities	Users (port planners) require disaggregated commodities in order to ensure that they can validate the demand through further market research and by obtaining industry knowledge. Users (port planners) require disaggregated commodities to facilitate targeting specific transport customer markets and focused bulk terminal infrastructure planning.	Marine deep-sea

Req. ID	Requirement	Motivation	Quay wall extent
U2	Container physical types	The inclusion of container physical types in the modelling to inform infrastructure capacity and investments suitable to these physical types, for example quayside refrigeration units required for reefer containers, etc.	Marine deep-sea, Transhipped, Empty
U3	Container unpack position and transport modes	A requirement from the integrated nature of the surface freight planning models is to understand whether full quay wall containers are transported to their hinterland destinations in containers or are unpacked at or close to the port.	Marine deep-sea
R1	Disaggregated commodities adhere to related models	The adherence to established macroeconomic commodity classifications in the disaggregated FDM both to improve the accuracy of modelling through the ability to use economic datasets, and to enable the application and interpretation of results for various stakeholders and within various contexts.	Marine deep-sea
R2	Parameters applied to origin-destination data	The proposed container model must be applied to origin-destination flow data within the FDM. Thus the design of parameters should be such that it can be applied to the existing data structure.	Marine deep-sea
R3	Forecast year breakdown	Forecast horizon years need to overlap with the FDM horizon years, i.e. base year and years 2, 3, 4, 5, 6, 11, 16, 31.	Marine deep-sea, Transhipped, Empty
F1	Spatial disaggregation	Adherence to a spatial disaggregation of container detail per port as applied in FDM.	Marine deep-sea, Transhipped, Empty
F2	Percentage containerisation	Palletisable and containerisable commodities were identified and thus one would expect that a fairly large percentage if not 100% of these commodities would cross the quay wall in containers. Similarly bulk freight would prefer bulk terminals, creating a percentage containerisation per commodity, per port.	Marine deep-sea
B1	Weight limits enforced per container physical type	Imposed weight limits and enforced container weight reporting active since July 2016 would create an upper ceiling for container weight that can be included in the modelling parameter values.	Marine deep-sea, Transhipped
A1	Only palletisable freight should be in containers	This should be seen as a soft restriction that guides the researcher to identifying container content from the sampled data that is illogical and might be short-term incidents due to temporary capacity restrictions at bulk shipping terminals.	Marine deep-sea

This chapter introduced several User requirements (U) from port planner views implied in the container models objective of providing more accurate outputs than alternative methods. The proposed container modelling framework needs to relate to the FDM model, which introduced several Design restrictions (R). One Boundary condition (B) and One Attention point (A) was also identified.

2.5 Conclusion

The purpose of this chapter was to define research concepts and terminologies within the specific context of this dissertation. Several specific maritime, port, and shipping container definitions were tabled to define their relevance and applicability for this dissertation.

The title of this dissertation focuses on economic activity originating from a disaggregated economic input-output model. This disaggregation is done spatially and according to commodity groups of significance for transport purposes. The journey to obtain a breakdown of commodity groups from the SIC coding system was explained. This provides detail of how the final list of 83 commodities used by both the FDM and this dissertation was determined.

Another aspect of the research title focuses on the translation of the economic activity into shipping container demand. It is thus important to understand which of the said commodity groupings identified should be transported across the quay wall in containers. The concepts of containerisable and palletisable freight were defined to narrow down the scope of commodities that would most likely be found in quay wall containers.

The next chapter determines which quay wall container modelling techniques are available globally. The focus is to determine if these modelling techniques advise specific modelling inputs based on an environment where container content knowledge is available.

3. The state of the art in current container forecasting and modelling techniques

3.1 Introduction

Scholars have argued during the last decade about the overestimation of port container demand. Much of this overestimation has been ascribed to the decline in trade and consumption caused by the global recession of 2008 and the impact it had on global trade volumes well into 2009 and even 2010. In section 1.4 it was explained that many port infrastructure planners work on forecasts that are generated by broad-stroke methods such as extrapolations from historic trends, GDP multipliers and expected growth in trade. These methods however often lead to overestimation of required capacity, impacting the ability of service providers to cover the fixed costs. A GDP multiplier as identified above is based on the historic relationship between GDP growth and container growth.

Various forecasting techniques related to container volumes, container terminals, container ships (number and size) and port infrastructure have been proposed in the last two decades by various scholars in the field. Some of the frequently cited scholars in this field are: Bontekoning, De Langen, Fung, Martin, Notteboom, Pallis, and Rodrigue. Some of their proposed methods and techniques are discussed in this chapter.

Forecasting techniques used include extrapolation, regression analysis, neural networks, clean sheet for new ports, and inter-port competition analysis models. Aspects included in forecasting techniques by these scholars were: local GDP growth, global trade growth, port interaction and competition, exchange rate fluctuations, fuel price, population growth and demographic changes. The one aspect many of them chose to ignore was the content of the containers, although some emphasised the importance, but excluded it due to not knowing the content.

The objective of this chapter is to identify input parameters used historically in modelling container terminal forecast throughput to predict container port and container terminal capacity expansions. The author started with a key word search, considering search text strings such as: 'container port'; 'forecast methods'; 'input parameters'; 'container modelling'; 'container capacity planning'. These key words (with a variety of synonyms), search individually and in various combinations, on academic research databases such as SCOPUS, Web of Science, and Science direct returned a vast number of results. The articles found were then sifted for relevance, coded and analysed using ATLAS.ti. This analysis produced a list of interesting linkages and influencing factors that pointed towards forecasting successes or challenges. In the process specific authors were identified who repeatedly publish on this topic, and searches were conducted for further relevant publications by these authors. Citations and references of these relevant articles were analysed and included if found to be of relevance. Key word searches for the Top 50 World container ports listed by JOC (Salisbury, 2015) were also done to find specific forecasts and modelling techniques for these ports. These results were included in the analysis where relevant.

Once a comprehensive article list was compiled and techniques and input parameters summarised, this list was secondarily coded for recurring techniques and input parameters, as described in section 3.2. To improve the manageability of this endeavour, the following guidelines were used as these imply increased importance in terms of container trade and therefore attract a higher proportion of the forecasting efforts:

- Port size: The focus is on the Top 50 World container ports by volume as these ports attract forecasting endeavours due to their expansion and efficiency requirements.

- Port growth rate: The focus is on fast-growing ports as it increases the need for improved planning to manage the growth.
- High economic growth regions: The focus is on high GDP growth and trade growth regions as high consumption and container growth rates are expected in these regions.
- Port networks: The South African port network resides under one management and legislation. Guidelines from similar groupings and their modelling approaches would be beneficial to this study.

At the end of this analysis, hundreds of article abstracts were scanned for relevance. Over a hundred articles have been included and coded for their modelling techniques and input parameters.

3.2 Literature research discussion

3.2.1 Introduction

Most of the articles found in scholarly journals covering the relevant topics and themes described in the previous section were descriptive in nature. This observation correlates with the findings from Pallis et al. (2011), who found a limited number of articles related to what they called 'forecasting studies'. In their study they analysed 395 port studies published in journals between 1997 and 2008. They defined seven research themes based on analysis of the papers' content:

- Terminal studies;
- Ports in transport and supply chains;
- Port governance;
- Port planning and development;
- Port policy and regulation;
- Port competition and competitiveness;
- Spatial analysis of seaports.

Of these themes the most relevant to this dissertation is *Port planning and development*, with some relevance to *Port competition* and *Spatial/regional aspects*. Many of the other studies they found related to short-term planning, or port and terminal operational aspects. As Pallis et al. (2011) highlighted (*emphasis* added by author):

> 'Although forecasting demand for port services *would be a powerful tool* for governments, port authorities, terminal operating companies and port users, *relevant scientific research is limited*'.

Sufficient literature detailing forecasting models and techniques using various input parameters were however obtained to identify a progression in focus and in the prominence of the extent of port planning over the past four decades. This led to the identification of four eras within port research with the following broad definitions and time frames:

- Understand the local port (pre-2000);
- Attract and cater for port hinterland (2001-2005);
- Understand impact of nearby ports (2006-2010);
- Port competitive ability (2011-2017).

Although the focus of some individual articles falls outside these categories and timeframes, they are discussed within these broad sections as a guideline.

3.2.2 Understanding of the local port (pre-2000)

Commodity detail has been included in forecasting as early as the 1980s, although the focus was on total port volumes at that stage and not containers only. A selection of relevant sources is provided in Table 3.1.

Over four decades ago Batchelor and Bowe (1974) recognised trade growth and trade partnerships as input parameters. They included these modelling parameters in a UK forecasting port study using a general equilibrium approach.

Dagenais and Martin (1987) were pioneers in recognising a long term disaggregate forecast including a view on the percentage containerisation of various commodity groups. They highlighted the effect of traded commodities, the importance of the containerisation effect, and that major ports developed more complex forecasting models. Rotterdam considers commodities and New York the 'economic wellbeing of surrounding hinterland states' as well as foreign trade volumes as forecasting input. This is relevant to the South African context, since the South African ports serve a Gauteng hinterland with significant trade volumes.

Davis (1983) in a study on all USA container ports emphasised aspects such as changes in foreign trade and domestic markets and port pricing policies to be considered as input parameters.

The focus in this era was to understand the local port and its future. Large volumes of freight were still moved in bulk with containerisation emerging in prominence. Commodity detail was thus mostly known and used as modelling inputs for bulk terminals.

Table 3.1: Selected sources for the container modelling era: Understand the local port (pre-2000) (sorted by date)

Author, year	Modelling focus	Modelling technique	Modelling Dimensions
Batchelor & Bowe (1974)	UK international trade	General equilibrium approach	Trade agreements; Trade partner economic growth; Domestic GDP
Haven van Rotterdam(1980) included in Dagenais and Martin (1987)	Freight forecast for Rotterdam	Freight flow model	Econometric import and export functions by commodity (GDP for Netherlands and neighbours) Including proportions of different commodities by container
Expansie van Antwerpen (1981) included in Dagenais and Martin (1987)	Freight Forecast for Antwerpen	Trend extrapolations	Trend extrapolations with mixture of trend analysis and shift and share
Davis (1983)	USA Port Impact	Input-Output Modelling	Changes in foreign market demand; Changes in domestic market demand; Comparable imports/exports (perfect vs no substitution); Port pricing policies
Dagenais and Martin (1987)	Forecasting container traffic for the Port of Montreal	Long term disaggregate forecast	Trends in international trade Commodity effect Trading partner effect Containerisation effect Hinterland effect Disaggregate (by category and region)

3.2.3 Attraction of and catering for the hinterland (2001–2005)

In the late 1990s and early 2000s cognisance grew of the port's service to the near and further hinterland. Ports in competition with nearby ports also tried to establish preference from the nearby hinterland to increase income generated from handling bulk freight and containers. This lead to a higher emphasis on economic activity in the port's nearby hinterland becoming part of the forecast input parameters. A selection of relevant sources is listed in Table 3.2.

The Port of Hong Kong serviced trade between China and the international community due to the historic political environment. Fung (2001) recognised the effect of regional port interaction on the Port of Hong Kong and the subsequent move of container volumes away from Hong Kong to alternative ports in mainland China. Fung (2001) considers price sensitivity and service competitiveness. He concludes that 'When the markets of the two ports overlap, the market shares will depend on the prices they charge and on how well they meet the needs of the shippers and shipping lines'.

Table 3.2: Selected sources for the container modelling era: Attract and cater for hinterland (2001–2005) (sorted by date)

Author, year	Modelling focus	Modelling technique	Modelling Dimensions
Fung (2001)	Throughput forecast informing infrastructure planning (Hong Kong vs Singapore)	Vector error correction model; supply meeting demand curves Regressing cargo volumes Regional competition Unexpected economic up/downturn	Container terminal throughput; Value of China's foreign trade; Value of Southeast Asia's foreign trade; Hong Kong's container terminal tariff; Singapore's container terminal tariff.
De Langen (2003)	Establish modelling parameters and apply to Europe Far East trade route for 1980–1995	Detailed disaggregate modelling	Volume of trade and international transport flows (GDP, export quote of economics, direction of trade and value density of trade; Containerised proportion of transport flows (containerisable share, containerisation rate and the share of shipping in international trade).
Kawakami and Doi (2004)	Port capital formation and effect on economic development	Lag-augmented vector auto-regression (LA-VAR) approach	GDP multiplier; Private capital; User transport cost; Port capital in Japan.
Lam, Pan, Seabrooke and Hui (2004)	Port of Hong Kong container forecast	Mathematical modelling	Population; Trade values of imports/exports; GDP multiplier.
Notteboom (2005)	Port regionalisation	Descriptive	Hinterland networks; Intermodal corridor development.
Syafi'i, Kuroda and Takebayashi (2005)	Indonesia container port expansions	Mathematical modelling with trend extrapolations	Container throughput; GDP; Population; Exports and imports.

De Langen (2003) emphasised the importance of disaggregating economic activity to enhance the forecasting granularity. Based on forecasts for Europe–Far East trade during 1980–1995, he included concepts such as containerisation rates and trade partnerships in the modelling framework.

Kawakami and Doi (2004) published their work on forecasting the container port volumes for Japan, but on very high-level input elements including a GDP multiplier, capital investments and transport costs. Some port comparison was indicated on costs, but the focus was on Japanese ports as entity and thus on collectively serving all of Japan as hinterland.

Lam et al. (2004) used explanatory factors such as population, trade values of imports and exports, and a GDP multiplier to forecast traffic for Hong Kong, the world's busiest container port at the time. Due to changes in the political and economic environment since their 1997 forecast, they proposed updating their method to incorporate new factors such as a shift in the content of containers being traded, but did not incorporate content.

Notteboom (2005) emphasised the importance of hinterland networks and adapting the networks to encourage corridor development. He proposed combining deep-sea volumes with intermodal corridors linking terminals in hinterland areas to ports to enable ease of freight movements from and to the natural hinterland of ports. This article introduced the importance of integrated port and hinterland freight forecasts. One cannot be done in isolation from the other, since infrastructure development cannot be disconnected.

Syafi'i, Kuroda and Takebayashi (2005) used container throughput, GDP, population, and exports and imports as model variables to forecast container throughput for a new port in Indonesia. The proposed Durban dig-out port can be seen as a new port development, although it will be an extension from a nearby port. Shipping lines will not berth in both ports, but will have to choose between the two. The new Durban port will serve hinterland industries, and thus the container content could provide valuable insight as to the requirements and forecast volumes for such a port.

This era in port development and forecasts introduced the concepts of integrative modelling reaching into the port hinterland. The domestic transport infrastructure is seen as an extension of the port infrastructure. For the South African context the port hinterland should be viewed as not only Gauteng, but also sub-Saharan countries with lower levels of port development and especially landlocked nearby neighbours, such as Lesotho, Swaziland, Botswana, Zambia and Zimbabwe.

Many scholars in this era and following into the next one used a GDP multiplier as one of their forecasting elements. This concept is based on historic analysis of parameter influence, with a trend extrapolation done to determine a forecast. Some of these show GDP multiplier values over a wide range depending on the port's dominance and size in the region and the hinterland it serves. Values for GDP multipliers of between 2 and 3 are common and values even higher than three are often used.

Another aspect introduced is population as an input element. The details of population growth and the expected future affluence of this population provides an indication of expected consumption patterns for consumer goods such as basic and processed foods, furniture and technology items.

3.2.4 Understand the impact of nearby ports (2006–2010)

One aspect often taken into account is inter-port competition, and with the hinterland emphasis in the previous section this has already surfaced in many of the articles discussed. One port or terminal can obtain significant growth through efficiency differentials with nearby ports. These efficiencies can be related to port entry, available berths, quay wall infrastructure, back-of-port space and equipment, or improved linkages to local and hinterland industries. A selection of relevant sources is listed in Table 3.3.

Hesse (2006) proposed an attribute analysis technique involving aspects for trading partners, hinterland and economic cluster developments with port regional competition included in the parameter framework. This was done as part of a study to forecast container volumes for port regional planning in northern Germany. These northern German ports compete with dominant Western European ports like Rotterdam and Antwerpen.

Table 3.3: Selected sources for the container modelling era: Understand the impact of nearby ports (2006–2010) (sorted by date)

Author, year	Modelling focus	Modelling technique	Modelling Dimensions
Hesse (2006)	Port regional planning for northern Germany	Attribute analysis	Trading partners; Hinterland developments; Economic cluster developments; Regional port competition.
Yap and Lam (2006)	Port competitiveness East Asia	Statistical methods on time series data, Co-integration test	Trade growth; Share of regional capacity; Hinterland development.
Yap, Lam and Notteboom (2006)	Port competitiveness East Asia	Historic analysis of parameter influence	Trade growth; Share of regional capacity; Transhipment competition; Hinterland development.
Garratt (2006)	Long term investment focus	Trend extrapolations	Focus on the historic relationship between GDP and container volumes.
Raguram and Gangwar (2007)	10–20 year volume forecast, Indian Ports	Linear Regression	The growth of container traffic driven by: - International trade growth; - Penetration of containerisation; - Hub and feeder service structure.
Ho, Ho and Hui (2008)	Large infrastructure investments: Port throughput and capacity for Hong Kong	Dynamic Port Performance model (DPPM)	Macro political factors; Economic risk factors; Port competition factors (price and congestion); (with scenario and sensitivity analysis).
Gosasang, Chandraprakaikul and Kiattisin (2010)	Container throughput for the Port of Bangkok	Neural network technique	Domestic GDP; World GDP; Exchange rate; Population; Inflation rate, Interest rate; Fuel price.
Notteboom (2010)	Single gateway vs multiple gateway, South African ports	A generalised cost model to two alternative network configurations	Port efficiency; Trade region ODs; Cost Components (marine charges and port dues, cargo dues and terminal handling costs, inland costs, ship costs, time costs).

Ho, Ho, & Hui (2008) were among the first to introduce port competition as a proactive strategy that requires inclusion in the modelling approach. They included modelling elements for macro political factors, economic risk factors, port competition factors (price and congestion) and made provision for scenario and sensitivity analysis in their Dynamic Port Performance Model (DPPM). This introduction of price and congestion at port level is an important aspect of the modelling approach that needs to be considered later in this dissertation. If competitive ports with sufficient capacity should be built along the east and west coast of sub-Saharan Africa, they would compete for hinterland traffic using South African ports.

Yap and Lam (2006) had a similar approach to input elements in their forecast study for East Asian container ports, but used statistical methods on time series data as a forecasting technique. Yap et al. (2006) used a similar approach, but focused on historical analysis of parameter influence and introduced transhipment competition as an input parameter, the first authors to have also looked at this phenomenon between competitive ports.

Garratt (2006) emphasised the importance of the historical correlation between container traffic growth and GDP growth. Gosasang et al (2010) proposed a neural network technique to forecast container volumes based on macroeconomic variables, based on domestic GDP, world GDP, exchange rate, population, inflation rate, interest rate and fuel price as variables.

Where Fung (2001) considered elements like price sensitivity and service competitiveness in port competition. Wilson and De Vuyst (2007) emphasised forecasting errors in the USA where efficiency gains were expected to translate to volume growth. If competing ports are all continuously improving, a price and service differential cannot be easily achieved.

Almost a decade ago, Wilson and De Vuyst (2007) argued that the supply and demand for container shipments is a market of its own, regardless of the contents of the containers. They do, however, acknowledge that a shift in container contents is taking place and that it is a missing link in their forecast that needs to be captured in the future.

Notteboom (2010) discussed the importance of shipping line decisions to visit multiple ports in the South African port network or only visit one and in the process emphasised the cost components, port efficiencies and relevant trade regions serviced by these ports. Notteboom emphasises the lack of substitute ports along the sub-Saharan African coastline, and thus the dependence of neighbouring countries on the South African port system. De Bod and Havenga (2010) highlighted the extent of foreign investment aid received by the sub-Saharan Africa region, and the need for greater forecasting accuracy to aid the prioritisation of effective infrastructure investment expenditure of this investment.

3.2.5 Port competitive ability (2011–2017)

The previous section addressed the rising awareness of the impact of nearby ports. In the high GDP growth environment leading up to the global recession of 2008, this caused some competition for the available growth to emerge. With trade volumes plummeting post-recession, port operators lost volume and income and full-blown competition emerged. This era led to many publications on container forecasts focusing on the impact of the recession, which were mostly short- to medium-term focused. These were followed by how ports can retain their volumes based on the port's ability to compete within its regional environment. A selection of relevant sources is listed in Table 3.4.

Veenstra and Notteboom (2011) focused on the existing expansion plans and how these plans are adjusting to accommodate volume changes due to the impact of the recession. This article had a short- to medium-term focus on the Yangtze River container port network in this economic region in China. GDP and population growth were the input parameters in focus. They also considered the effect of the distance to the nearest deep-sea port in this hub-and-spoke transhipment river environment, and port efficiency comparison also played a role in shipping line preference while the freight owners' biggest concern was handling costs.

In Australia, the Department of State and Regional Development of New South Wales (2011) is responsible for performing container forecasts for Melbourne, Sydney, Brisbane, Fremantle and Adelaide. They base their forecast on globalisation and world economic growth over the next 20 years. No reference to port competition is done since their forecast is for the combined port network, including a hinterland focus as with the 2000–2005 era above.

Table 3.4: Selected sources for the container modelling era: Port competitive ability (2011–2017) (sorted by date)

Author, year	Modelling focus	Modelling technique	Modelling Dimensions
Veenstra and Notteboom (2011)	Regionalisation effects Port ownership	Analysis of existing expansion plans Multivariate variance analysis	Existing expansion plans (Cranes, berths, yard size, berthing capacity, Quay length, # of terminals); Concentration of ports and terminals around economic region; Estimates for last 3 years based on GDP and population; Effect of outside ownership on throughput.
Notteboom (2011)	Container hub placement in South Africa	Multi-criteria analysis (MCA)	Decision Criteria: - Port users (demand vs supply profile of port, market profile of the port); - Terminal operators/investors (Transnet) (view on NPV, future expansion, capacity to connect land infrastructure; - Community (lifetime effects on the environment, congestion and the economic development of South Africa and the wider sub-Saharan Africa region).
Fraser and Notteboom (2012)	Ports of South Africa, Walvis Bay, Maputo, Madagascar, Mauritius	Theoretical spatial development model as well as the traffic analysis	Distance (Road and rail); Historic volume shift; Port Rivalry; Concentration-deconcentration factors.
Notteboom (2012)	Shipping Route comparison	Comparative route analysis (Suez + Algeciras vs the Port of Ngqura)	Distance; Transit time; Cost; Risk.
Monios, Wilmsmeier and Rodrique (2016)	Competition and complementarity between seaports and hinterlands	Descriptive	Overview of regional differences to develop a framework. Identifying type of distribution activities and suitable locations (near port and hinterland); Dimensions: geographical, economic and logistics settings.

In section 1.5 Transnet was introduced as South Africa's only port operator. Notteboom (2011) performed a long-term comparative impact study on the Ports of Ngqura, Durban and Richards Bay. This study's objective was the placement of a new regional container hub and used decision criteria from the perspective of port operators/investors (Transnet), the communities affected by these ports (South Africa and sub-Saharan Africa) and port users (shipping lines, transport operators, forwarders, consignors and consignees). The multi-criteria analysis results indicated the Port of Ngqura as the best alternative for a container hub with the Port of Durban in second place. The hypothesis was that port users would mostly be concerned with the availability, cost, quality and reliability of the nautical access, container terminals and inland access. Other concerns would be the scale and growth of the port and the connectivity of the port in wider maritime networks. From a market perspective, users would be concerned about the port reputation, the structure of the terminal operating business within the port, the presence of logistics activities in the port and the logistics focus of the port.

Notteboom (2011) further emphasised that Transnet as both the terminal operator and investor would be concerned with which of the three ports would provide the maximum NPV, has the best possibilities to expand in future, and the capacity to connect land infrastructure into the hinterland of Gauteng. This comes with the advantage of one combined infrastructure plan, but also with the responsibility of being the only alternative to ensure that South African industry can trade globally (Notteboom, 2011). This monopoly situation in the South African port system is not about to change soon (Havenga, Simpson, & Goedhals-Gerber, 2017), and thus the model framework needs to function within these boundaries. This could lead to complacency that could influence the timeliness of capacity expansions and thus accurate quay wall container forecasts based on validated demand are required.

On the other hand, the communities would be either concerned or excited about the short- and long-term effects of the construction and operation of a new container terminal on the environment, near port congestion and the potential economic development of South Africa and the wider sub-Saharan Africa region. This study addressed many of the dimensions highlighted by the literature discussed up to this point and provides a comprehensive background to the perspectives and requirements of port users, operators and environment. The study is focused on the South African context, but unfortunately does not propose a method to forecast the expected container throughput for this envisaged new container hub.

Notteboom (2012) followed the above study with a study comparing shipping routes of the Port of Ngqura with using the Suez Canal and the Port of Algeciras as transhipment ports. He used distance, transit time, cost and risk as modelling parameters with a large set of origin-destination combinations. The current Suez Canal expansion project would enhance the throughput and reduce transit time, but could lead to higher transit fees. The Cape route (via the Port of Ngqura) would become more competitive due to high transit fees through the Suez Canal, as well as better vessel economics, higher bunker costs and current slow steaming practices. The oil price is currently at lower rates than in 2012, thus the bunker cost might not be that applicable anymore. However, he argues that if Transnet introduces a competitive terminal pricing strategy for the Port of Ngqura this could be the start of a rise in south–south trade volumes between Asia, sub-Saharan Africa and South America. This could have an impact on both local trade and transhipment opportunities for South African ports. According to a study by Mchizwa (2014) on South African port policy, nothing of this nature had been implemented by 2014.

Monios et al. (2016) introduced a different view on the role of ports. They compared two alternative roles for port distribution. In one instance the port is the centre of the distribution and logistics activities and the hub around which the regional economic activity is driven. In the alternative role, the port is the link to the hinterland location where the economic activity happens, mostly driven by port congestion and scarcity of land for industry and container handling activities close to the port. They discuss this phenomenon around empirical evidence from locations around the globe. The result of this is that ports are in competition to service hinterland demand for container movements, but instances of complementarity are growing in numbers between ports and hinterland intermodal terminals.

3.2.6 Summary of progression of container modelling techniques

During the above analysis of previous forecasting efforts, a combination of several key input parameters was identified that are used to inform future container volumes. Table 3.5 summarises the progression over time from an inward-focused port forecast, to a wider scope of including the impact of the port hinterland, to recognising the full effect of the regional hinterland and finally the competitive nature of regional ports.

In summary, the common container modelling input parameters used by port planners and proposed as inputs for the objectives of this dissertation are:

- Trade growth and trade partnership changes and Economic cluster development;
- Economic factors:
    - GDP growth (local and global),
    - Relative exchange rates,
    - Population numbers.
- Port regional competition and efficiencies.

Table 3.5: Summary of analysis: Key focus of modelling parameters in container forecasting models

Year range	Frequently used modelling parameters	Key modelling focus
Pre 2000:	International trade Domestic GDP Commodities Containerisation effect Port tariff	Local port (bulk and some container) <u>Objective:</u> Understand local port
2001–2005	Container throughput Domestic GDP International trade Port tariffs Hinterland accessibility Port reputation and reliability	Local port and near hinterland <u>Objective:</u> Attract hinterland freight
2006–2010	Population size Regional port competition Economic systems and cluster development Trading partners and growth Containerisation effect Transport cost elements	Local port and regional hinterland <u>Objective:</u> Understand impact of nearby ports on regional hinterland
2011–2017	Local and international GDP Trading partners and growth Trends in nearby port volumes Expansion plans for nearby ports Port efficiency Port ownership	The port as part of and influenced by the regional port system <u>Objective:</u> Port-competitive ability

3.3 Research design requirements identified in this chapter

Several model design requirements as defined by Van Aken et al (2006) can be mentioned from aspects covered in this chapter. The list provided in Table 3.6 focuses on design aspects specifically applicable in the design of content-based quay wall forecasting models from the related literature studied. The focus remains on 'containers that cross the quay wall' in the South African context.

Table 3.6: Design requirements identified in Chapter 3 (Numbering continued from Table 2.5)

Req. ID	Requirement	Motivation	Quay wall extent
F2	Percentage containerisation	Introduced in Chapter 2. Dagenais and Martin (1987) recognised the containerisation effect on specific commodities and highlighted the percentage containerisation is an important modelling factor to consider for the split between bulk and containerised freight.	Marine deep-sea
F3	Disaggregated commodities	Introduced in Chapter 2 as U1 and R1. De Langen (2003) emphasised that disaggregation of traded commodities provide a better granularity and enhance accuracy of forecasts.	Marine deep-sea
F4	Port preference	Freight tends to gravitate to the port of least resistance being defined by distance, cost and/or time. Several authors in the era 2006-2010 stressed the point of port competition and this leads to port preference. In order to model this, specific historic content knowledge per commodity and country combinations would be required.	Marine deep-sea
A2	Port hinterland trade patterns	The 2001-2005 era introduced the concept of integrative modelling with an extent reaching into the port hinterland. For the South African context the extended port hinterland should be viewed as not only Gauteng but also sub-Saharan African countries. This design restriction introduces a level of complexity that is beyond the scope of this dissertation but worth highlighting as an influencer.	Marine deep-sea
A3	Hinterland economic structure	Trade activity would increase with countries where a favourable trade agreement is established, thus leading to port preferences related to certain commodity and port combinations, i.e. trade with BRIC countries would benefit mostly the Port of Durban to China and India. The frequent analysis of container content data (as done in Chapter 5) would provide valuable insight into shifts in trade partner activity that are important feedback to economists. (As such this is more a design restriction for the disaggregated input-output model than for the container modelling framework.)	Marine deep-sea, Transhipped

Req. ID	Requirement	Motivation	Quay wall extent
A4	Port competitive position	Port competition is a proactive strategy that requires attention from model users. Modelling elements for macro political factors, economic risk factors, port competition factors (price and congestion) are included.	Marine deep-sea, Transhipped
A5	Hinterland states: Investments	The economic well-being of hinterland states could create the financial capacity to invest in their own port infrastructure. This is relevant to the South African context, since the South African ports serve a Gauteng hinterland with significant trade volumes.	Transhipped
A6	Port hinterland integration	The result of this is that ports are in competition to service hinterland demand for container movements, but instances of complementarity are growing in numbers between ports and hinterland intermodal terminals. In the case of South Africa this would be cooperation between hinterland based container terminals and mostly the Port of Durban.	Transhipped
B2	Funding limitations	Developing nations cannot afford to build all capacity required everywhere immediately, thus wise spending at the right places is unnegotiable. Investment in specific competitive port infrastructure could in the long term redirect traded goods to sub-Saharan Africa ports away from the South African port system.	Marine deep-sea, Transhipped, Empty
B3	Port regulation and ownership	Transnet is the sole owner and investor for South African port infrastructure. This boundary condition could lead to complacency that could influence the timeliness of capacity expansions and thus accurate quay wall container forecasts based on validated demand would be beneficial.	Marine deep-sea, Transhipped, Empty

3.4 Conclusion

While the current literature reflects a host of aggregate parameters to forecast container volumes, no studies were found that utilises the propensity of commodities to containerise as an input variable, i.e. the current level of containerisation per commodity group, and the future potential for containerisation.

While many scholars refer to commodity detail or container content, it is not reflected in their modelling, but ascribed to a lack of available content data and complexity in modelling.

The focus for the remainder of this dissertation is to analyse the demand and supply side factors impacting container trade and to analyse available datasets to construct such a content-based container modelling framework. The two aspects that need to run in parallel are:

- Understanding the global container trade (demand-side) and container trade infrastructure (supply-side) landscapes. This includes the aggregate parameters that are used in current container demand forecasting techniques. The external environment is analysed to construct the framework in such a way as to ensure that the necessary dimensions are included to reflect key variables and influencers that could impact the future dynamics in the container shipping industry (Chapter 4).

- Analysing datasets and collecting primary research data to understand current container movements as well as how decisions made by freight owners, shipping lines and port authorities impact container movements. This will provide further insight to construct a container modelling framework that is representative of reality. Chapters 5 and 6 focus on understanding:
    - Bulk and container content (current commodities, volumes and preferences);
    - Port preference (by regional hinterland, commodity and trade partners); and
    - Container physical type preference.

4. Trends in the global container trade (demand) and container trade infrastructure (supply) landscapes

4.1 Introduction

The systematic literature review in Chapter 3 highlighted the key parameters used in container demand forecasting. The focus of this chapter is to analyse these parameters to elucidate their importance in container forecasting, as well as to establish whether there are additional parameters that should be included. This analysis is threefold, i.e. demand-side, supply-side and the impact of port networks.

The demand side details international trade focusing on trends, shifts, and patterns. Another aspect identified in the previous chapter was the global economic trends and patterns in GDP growth and trade growth connected with both developed and developing countries. Understanding where regional groupings are developing and how this would impact the South African port network is important.

To explain trends in the supply side, an overview of global shipping infrastructure facilitating trade would follow, i.e. routes, ports, ships, and handling infrastructure. Further detail needs to be investigated regarding the impact of trade infrastructure on a port, ship and container physical type level to determine which international norms and standards South Africa needs to adhere to.

The last section of this chapter is based on the emphasis found on port networks and port competition in the literature discussed in Chapter 3. A background search on the current sub-Saharan Africa port situation, trends in port clustering and regional interconnectivity of South African ports can further inform the decision on which parameters to include in the container demand modelling.

4.2 Demand side factors: Global economic trends

4.2.1 Population

The largest population globally is found in East and South Asia (between 1.5 and 2 billion people, i.e. between 20%–25% of total world population), while the highest population growth rates are in Africa (between 2% and 2.5%) and South Asia (1.5%). The implication is that Africa and South Asia are high growth markets for export trade due to growing demand for infrastructure (manganese, iron ore, coal) and consumables (food, beverages, machinery and electronics) (WorldBank, 2013). Population numbers drive consumption and the affluence distribution of the population drives the type of consumption and the basket of products they would be purchasing. Typically, as consumption matures, commodities are increasingly containerisable. This influences the trade volumes of different commodities and could impact the growth of trade with different trade partners as well.

4.2.2 Gross Domestic Product

In 2012, the cumulative GDP of the developing world reached the cumulative GDP of advanced economies as a percentage of the world total i.e. 50%. The GDP of the G7 countries increased from $7 trillion in 1980 (64% of the world total) to $33 trillion in 2012, which is now only 46% of the world GDP of $72 trillion. This shift in market share of the global economy is shown in Figure 4.1. Brazil, Russia and China are firmly placed in the top ten highest GDP nations in the world, although the GDP per capita for these nations still cannot compete with advanced economies. Despite China having the second-highest GDP in 2012 (8.2 billion US dollars), its growth is still remarkably high at 7.8%, with the country grouping called ‘developing Asia’ achieving an accumulated growth rate of 6.6%. (International Monetary Fund, 2014)

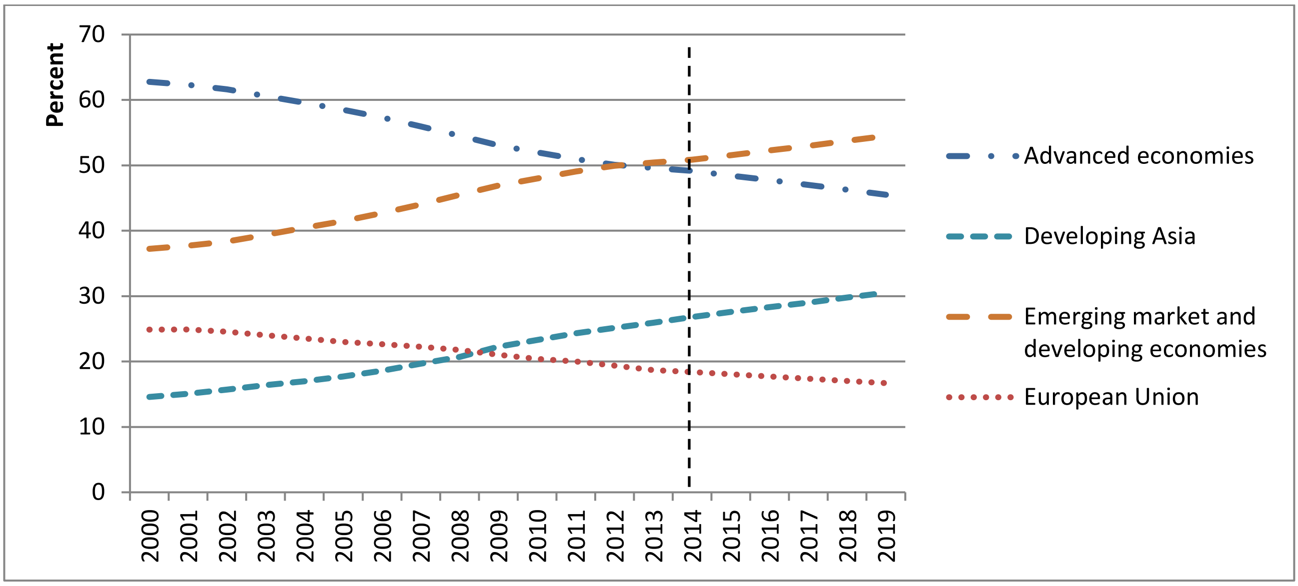

Figure 4.1: Shift in GDP for different World Economies as a percentage of World Total (International Monetary Fund, 2014)

China’s fast growth rate is achieved by a cost-effective labour production factor leading to a GDP per capita, which is only in 94th position. However, in 1960 China’s GDP per capita was only equal to 20% of the global figure of $444 per person. That figure has changed to 60% of the global figure of $10 171 per person. As China’s economy matures, labour will become more expensive and the structure of the global economy will be severely affected. Surveys in 2014 suggested that China’s manufacturing costs were then only 5% less than the USA (from 16% a year ago), meaning that the cheap production factor/higher transport cost trade-off is shifting and reshoring of production to developed countries is accelerating. By 2014 sub-Saharan African economies grew by 4.8%, Nigeria 6.3%, and South Africa 2.5% per annum, which reflects positively on the African Economy, but shows that South Africa is currently being impacted more by the decline of the developed world, than by the rise of the developing world. Global GDP growth in 2012 was 3.2%, down from 4% in 2011 (International Monetary Fund, 2014).

The relative growth rates of different economic regions have a direct impact on the volumes of economic trade between these regions, and thus container volumes. In other words, the high growth rate of affluence in the Chinese workforce would relate to a higher growth in import of consumer goods manufactured outside of China. Along with this, trade patterns with their major trading partners would impact container volumes to and from their trading partners as well.

In Chapter 3 many scholarly publications (Yap, Lam and Notteboom, 2006; Raghuram and Gangwar, 2007; Gosasang et al, 2010) linked port growth with economic and trade growth. The IMF (2014) reported stagnant growth between 2011 and 2013 in the developed world, including the USA, UK and the EU, as shown in Figure 4.2.

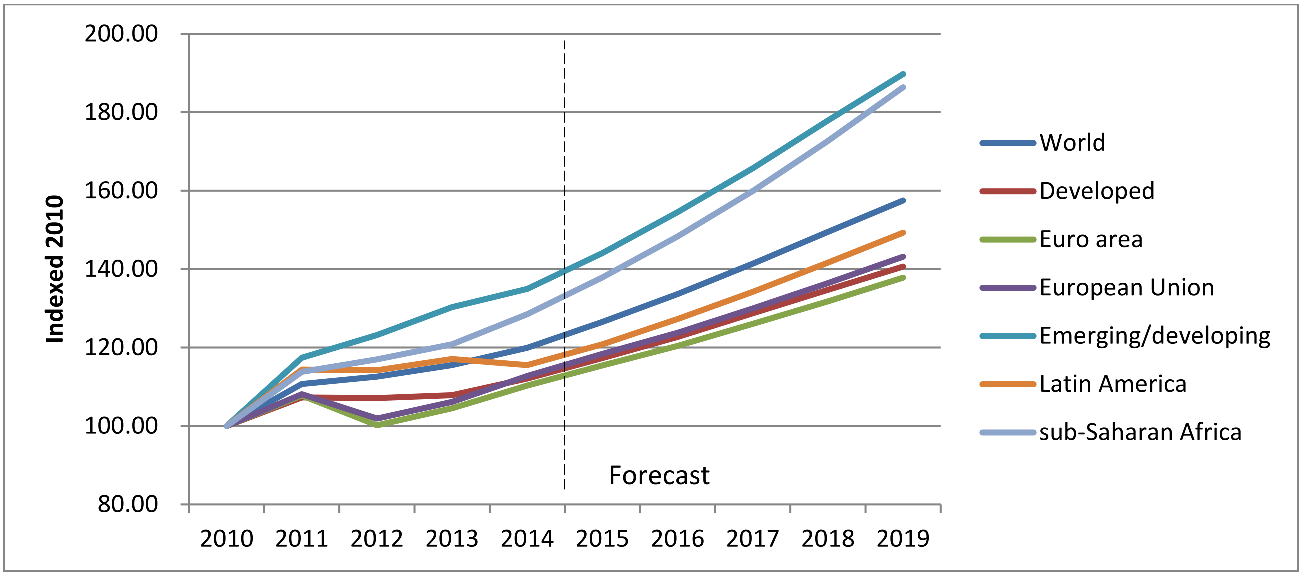

Figure 4.2: Regional economic growth forecasts (International Monetary Fund, 2014) (forecast from 2014)

The IMF in their World Economic Outlook Database (World Economic Outlook Database, 2014) illustrate the fastest expected growth regions being sub-Saharan Africa and other emerging/developing economies, also including China, and India. Ports should thus historically indicate the growth patterns related to 1) their own region, and 2) the growth patterns of the regions they are linked to with their majority trade. This should be true for the change in container throughput to date, and in future. Thus, from a container perspective, it is important to understand the major trading partners linked to container volumes today and how this would change in future.

4.2.3 Global trade

Figure 4.3 describes the trend of export volumes from 2000 to 2014 as compiled by the IMF (World Economic Outlook Database, 2014). The global trend shows a period of high growth (between 5% and 10%) from 2002 to 2008. Trade reached negative 10% annual growth in 2009, after the global economic crisis of 2008, and bounced back in 2010/11. During 2012 a stabilisation of growth, albeit below 5%, was observed.

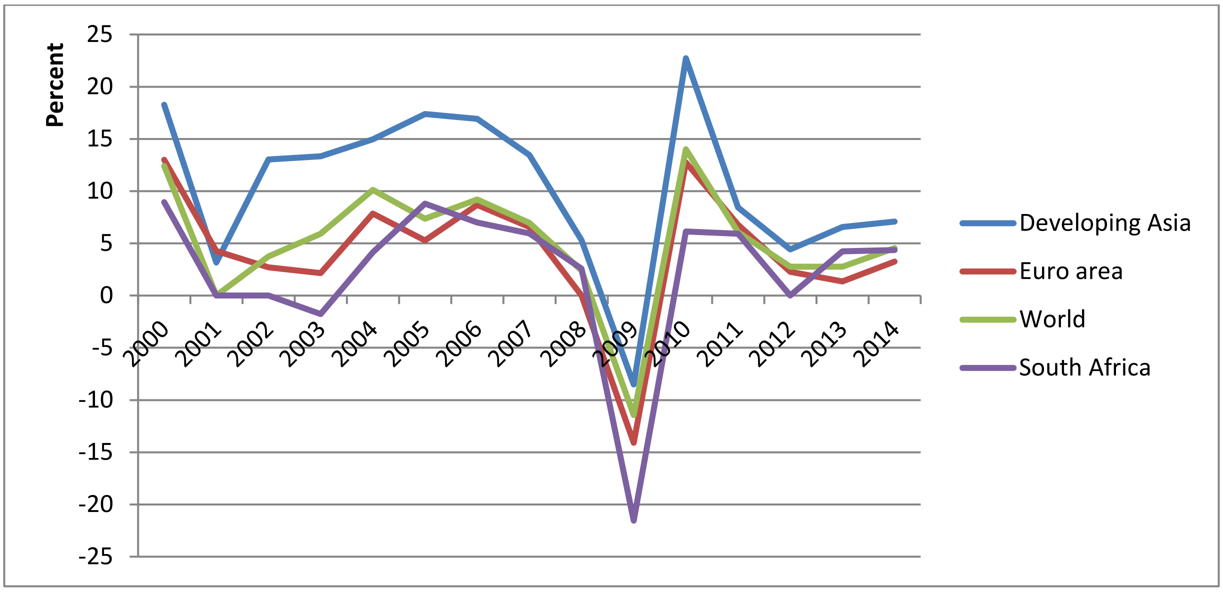

Figure 4.3: Change in volume of exports of goods per economic regions of the world (2000–2014) (International Monetary Fund, 2014)

According to the same IMF report, import volumes follow a similar trend, however, import volume growth for Europe turned negative in 2012, and import volume growth for South Africa remained constant at around 4%. For both imports and exports, developing Asia (including China) is above the global average, while the Euro area generally falls below, constantly bringing down the global average. Europe represents a large export market for South Africa and other developing countries, and the impact of its low import growth on those countries remains negative.

If import and export growth over the previous 10 years are added together South Africa ranks number 110 in the world at 8% growth in trade. The highest growth by far was experienced by Panama, with 58% growth in trade over the previous 10 years. The growth in usage of the Panama Canal over the past few years has been almost entirely driven by increased US imports from China passing through the canal on its route to ports on the US East and Gulf coasts. Other high-growth countries include Azerbaijan, China, and Paraguay (International Trade Centre, 2017).

Table 4.1 describes the balance of trade for major areas in 2016 measured in US dollars. As reflected, the most positive balance of trade is experienced by Asia, BRICS and Greater China; these countries are responsible for the bulk of the world's electronic equipment and machinery exports. South Africa and America both have a negative trade balance.

Table 4.1: Trade balance of country groupings (2016) (International Trade Centre, 2017)

Billion US Dollars, 2016	Import Value	Export Value	Trade Balance
Asia	5 849	6 433	583
BRICS	2 340	2 924	584
Greater China	2 377	2 917	539
Africa	450	328	-123
Europe	5 869	6 130	261
MERCOSUR	226	288	62
SADC	136	139	3
South Africa	75	74	-1
America	3 577	2 722	-855
Developed economies	**9 039**	**8 452**	**-586**
Developing economies	**6 963**	**7 397**	**434**

When grouped, developing economies have a positive trade balance, while the developed world has a negative trade balance. Aside from the South American trade group of MERCOSUR, which imports mostly machinery equipment and Greater China, which imports mostly electrical equipment, all other country groupings import mostly fuel or crude oil. The developed economies export mostly machinery equipment, while the developing economies export mostly fuel and crude.

The majority of high value trade is in fuel and crude, and it is these products that most impact on countries' balance of trade. This dependency on oil proved problematic for some developing economies. A number of countries, such as those in East Asia, have managed to grow their exports to an extent that they outvalue the necessary fuel and crude imports. Developing alternative energy sources is also essential to ensuring that countries' trade balance and exchange rates aren't too influenced by the value of fuel and crude imports. Another concern with the current trade paradigm is whether the global negative balance of trade with Asia, particularly China, can be sustained.

The South African trade balance is based on value, but not on weight as will be seen later. If an increase in export value is not established or continuous foreign investments found, a significant exchange rate shift and/or reduction in imports would be imminent. This could have a significant impact on port container volumes in the medium-to long-term. If export value cannot be raised, no funding would be available for raising imports due to a negative trade balance. This can be temporarily done, but is not sustainable in the long term without other external funding.

Global shipping route volumes are also changing with global economic and regional growth facilitated by new and extended trade agreements. Growth in Africa and groupings such as BRICS amongst others will increase volumes on shipping routes past South Africa. At the same time current completed and planned expansions to the Suez and Panama Canal systems might divert traffic away from South Africa as a transhipment port hub. Thus, changes in the global shipping network could have significant macro scale impacts on port infrastructure requirements.

Specialisation drives globalisation, which relates to an increased level of trade between countries. This trend can only continue up to a certain point, since 100% trade between all countries is not practical. The maximum level of trade achievable is yet to be determined, but Figure 4.4 shows the growth in trade tapering off since the 2008 recession. Ballou (2004) describes that specialisation increases productivity through economies of scale and reducing unit cost. This stimulates the trade of lower-cost goods versus producing it locally. Production globalisation is therefore driven by specialisation, and can be sustained as and when transport ability supports it. The rise in oil prices up to 2014 and subsequent decline, swung the scale first towards localisation, and then back towards specialisation. In this current lower oil price environment transport growth could keep on outstripping GDP growth.

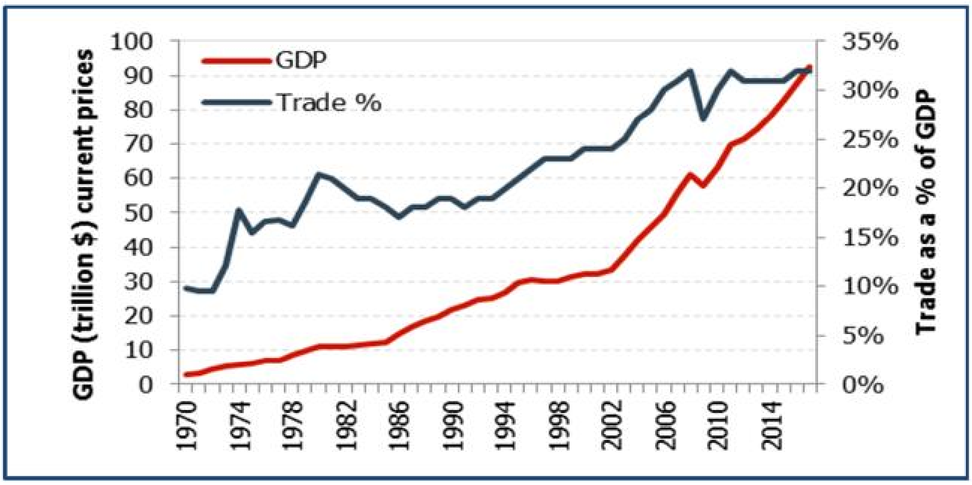

Figure 4.4: Global GDP growth and global trade as a percentage of GDP (Havenga, Simpson, & De Bod, 2014)

Koppen (1995) and Notteboom & Rodrigue (2009) both argue that a (un)natural limit for the trend exists. They argue that the consolidation of resources and production technology could lead to a reversal of globalisation (relocalisation) over the medium to long term. The trend, therefore, where points of supply are often geographically far distant from the point of demand, causing pressure on the transport system, could reverse. In addition, increasing scepticism about GDP growth as the key indicator of wealth and the continued emphasis on the carbon footprint of transport, are factors that could accelerate the drive towards relocalisation. A New Zealand NGO promoting sustainability, predicts that manufacturing will become more localised by 2025. They argue that certain industries might prove to be more 'strongly sustainable' to import, while others might move towards local manufacturing. In these cases manufacturers will justify imports, but they will still have a very limited portion of the input elements imported. This could significantly impact the historic link between transport growth and GDP growth over the medium to long term, having a significant impact on container volumes (Sustainable Aotearoa New Zealand, 2009).

Nash-Hoff (2016) refers to over 300 case studies of companies in the USA that have reshored parts of their business between 2010 and 2016, amounting to 100 000 manufacturing jobs returning to the USA. The Reshoring Initiative (cited in Nash-Hoff, 2016), an organisation promoting the benefit of reshoring for companies in the USA, estimates that a quarter of offshored manufacturing would return to the USA if the total cost of ownership is used in supply chain calculations.

This is partly attributable to China’s shift up the value chain of manufacturing and manufacturing input costs in the country simultaneously increasing. The implications of this are that low-value manufacturing moves to Southeast Asia (Vietnam in particular) and the US market looks for cheaper alternatives for electrical and other manufactured goods from source markets such as Mexico. Data shows that exports from China to the United States have been growing at a much slower rate than those from Mexico, which have grown at an impressive 68% since shortly after the recession (Ogard, 2013).

4.2.4 Global container trade

The demand for intermodal transport as a logistics solution has increased sharply over the past decade due to the time efficiencies, flexibility and economies of scale that it offers as an integrated transport solution.

4.2.4.1 Containers that cross the quay wall

The growth in container volume is driven by two factors: an increase in international trade which increases the tonnes of goods to be moved across the globe and an increase in the propensity to containerise commodities previously handled as break-bulk.

Global GDP grew from $11 trillion in 1980 to $72 trillion in 2012, an annual growth rate of 6%. Global GDP is forecast to grow to $98 trillion by 2018 with moderate growth expected over the next 30 years. Global trade as a percentage of GDP grew slowly from 1% in 1820 to 10% in 1970, and then accelerated, but this trend is now mature and no further significant rise is forecast. Therefore, global trade growth (relative to GDP) as a multiplier of container growth is disappearing fast, as was shown in Figure 4.4 (Havenga, Simpson, & De Bod, 2014).

Figure 4.5 shows that global container volumes handled by ports increased from 71 million TEUs in 1985 to 750 million TEUs in 2012, an annual growth rate of 9%. This was estimated to be 780 million in 2013 and to grow to 818 million in 2014.

The 430 million full containers handled in 2012 carried 3.8 billion tonnes of cargo, compared to the 5.5 billion tonnes of total international trade cargo, resulting in container penetration of 65.9%, up from 39% in 1990. The very high growth of 9% per annum observed over three decades to 2012 can be ascribed to the propensity to containerise from a low base. This number is high and further penetration on a global scale is becoming less likely.

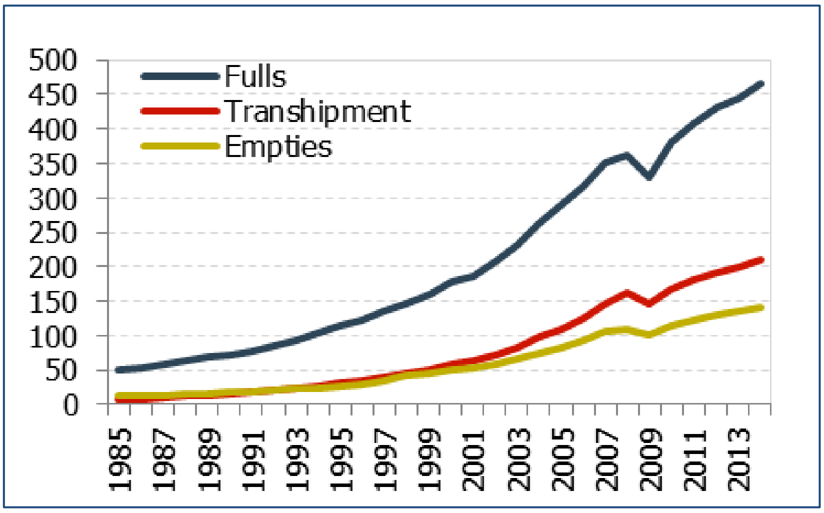

Figure 4.5: Global container volume growth, 1985–2014 (Drewry, 2015)

Garratt (2006) also confirms that the slowing of containerisation, as shown in Figure 4.6, is due to the maturing of the containerisation concept. Although certain mining commodities like power station coal, iron ore, and crude oil, will never be highly containerised if at all; many other high-value manufactured goods have already been or are close to 100% containerised. Havenga and Van Eeden (2011) showed that inevitably saturation in the propensity to containerise will be an important factor in accurately forecasting container demand. This would effectively remove the container penetration multiplier relative to GDP and container volumes will then grow linearly with trade growth.

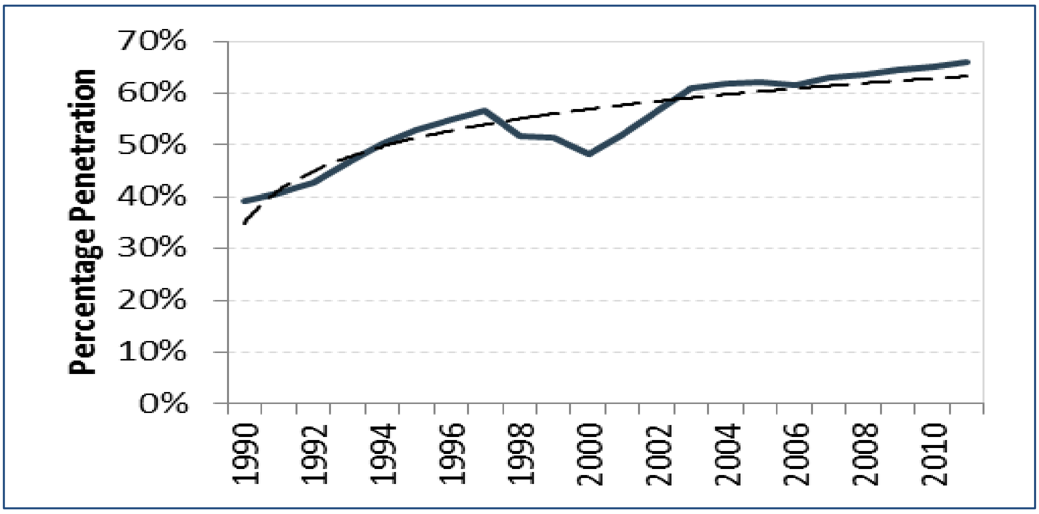

Figure 4.6: Percentage of global tonnes shipped in containers (Drewry, 2015)

In addition, increasing economies of scale, consolidation practices and better packaging material efficiency leads to tighter packaging solutions. Thus, the contribution that the container load factor made to the container growth multiplier is also disappearing (Garratt, 2006).

Across the board, the factors that caused global container volumes to grow up to 2012 at a more rapid rate than global GDP are diminishing, which will flatten out the rate of global container growth.

Quay wall container movements are also dependent on the volumes of empties and transhipment containers derived from international commercial transport network designs. Figure 4.7 shows empty and transhipment containers as a percentage of full containers.

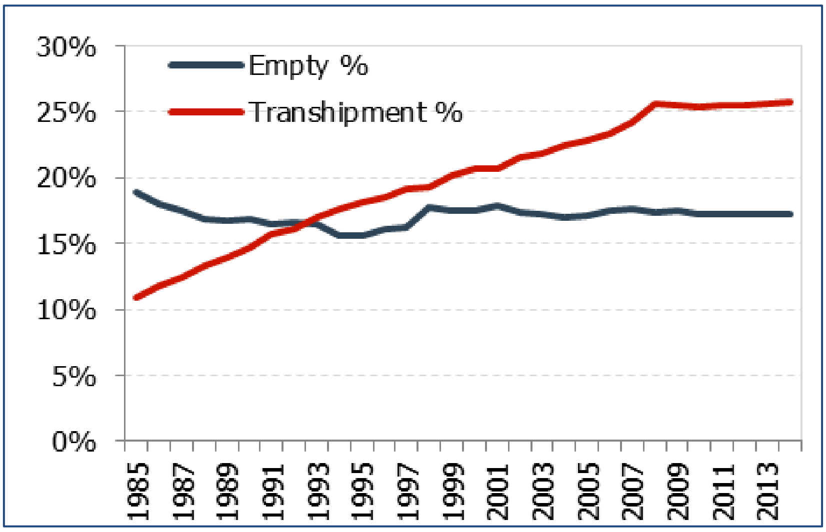

Figure 4.7: Empty and transhipment containers as a percentage of full containers (Drewry, 2015)

Empty container movements as a percentage of full containers globally have not moved beyond the 16–19% band in the last 30 years and have been confined to an even narrower band (17–18%) in the past 15 years. The volume and location of empty container movements are determined primarily by the directionality of trade flows that can share the same containers and equipment. Barring major industrial or spatial reorganisation in the world markets or the emergence of highly versatile equipment, very little is expected to change with respect to empty container movements in the medium term. Transhipment, on the other hand, is a logistics solution and supply side modifier that is only loosely related to the actual demand for transport. Transhipment is the result of network design and ports that can offer efficient transhipment solutions and therefore induce shipping lines to reconfigure routes. Transhipment trends have also matured over the past decade, staying between 25–26% of all container movements. Ports will have to develop very specific and robust business cases around certain routes and present competitive and complementary service offerings to obtain more market share in transhipments (Rodrigue, 2016).

4.3 Supply side factors: Trade infrastructure

4.3.1 Major ports

According to the Journal of Commerce (2017), nine of the top 10 container ports by TEU volume are in the Far East and one in the Middle East. The top eleven through twenty includes one in the USA, and three container ports in Europe, but the other six are also all in the Far East. The rest of the top 50 ports by volume are scattered across the globe.

Analysing the JOC Top 50 ports by growth for 2011 to 2016, indicates a number of ports growing fast, while others are stagnant or declining in container throughput. Table 4.2 shows the ports growing in TEU volumes by more than 5% per annum, and those growing by less than 1% per annum over the five years. Most of the fastest growing ports were in the Far East, the top five fastest growing ports are in China. Two exceptions are the Port of Algeciras Bay in Spain and the Port of Marsaxlokk in Malta. Both these European ports showed significant growth. Notteboom (2012) identified the Spanish port as a major east-west transhipment port that contributes to this high growth experienced. The stagnant and declining port container volumes were found in the USA, Germany, Japan, India and Middle East among other locations. One notable exception was the Port of Hong Kong, China, being a Top 10 port showing a significant decline of -4.3 % per annum over the five years. This might be ascribed to a regional shift between the Port of Hong

Kong, and the other top 50 ports in China being among the fastest growing ports. Fung (2001) predicted this shift away from Hong Kong towards mainland China ports in 2001, a phenomenon also described by Notteboom and Rodrigue (2009). The last African port previously on the Top 50 list, Port Said East in Egypt slipped completely off the list in the last year from being number 41 in 2015. This can possibly be ascribed by shifts in major trade routes and transhipment moving away to the Port of Algeciras Bay in Spain (Notteboom, 2012).

Table 4.2: A sample of the Top 50 ports showing significant growth/decline 2011–2016 (Journal of Commerce, 2017)

Port	Country	Region	Top 50 Rank		Annual Growth	Volume (Million TEU)					
			2016	2015	2011-2016	2016	2015	2014	2013	2012	2011
Ports increasing in volume >5.0% per annum (2011-2016)											
Dalian	China	Far East	15	15	9.3%	10.0	9.5	10.1	10.9	8.9	6.4
Yingkou	China	Far East	24	24	8.3%	6.0	5.9	5.8	5.3	4.9	4.0
Xiamen	China	Far East	16	16	8.2%	9.6	9.2	8.6	8.0	7.2	6.5
Ningbo-Zhoushan	China	Far East	4	4	8.0%	21.6	20.6	19.5	17.3	16.8	14.7
Qingdao	China	Far East	8	7	6.7%	18.0	17.5	16.6	15.5	14.5	13.0
Columbo	Sri Lanka	Far East	25	28	6.0%	5.7	5.2	4.9	4.3	4.3	4.3
Algerciras Bay	Spain	Europe	32	33	5.7%	4.8	4.5	4.6	4.5	4.1	3.6
Guangzhou Harbor	China	Far East	7	8	5.6%	18.9	17.2	16.2	15.3	14.7	14.4
Manila	Philippines	Far East	35	35	5.5%	4.5	4.2	3.7	3.8	3.7	3.5
Marsaxlokk	Malta	Europe	47	49	5.5%	3.1	3.1	2.9	2.8	2.5	2.4
Port Klang	Malaysia	Far East	11	12	5.3%	12.4	11.9	11.0	10.4	10.0	9.6
Ports Stagnant or decreasing in volume <1.0% per annum (2011-2016)											
Hanshin Ports	Japan	Far East	29	31	0.9%	5.0	4.9	5.3	5.3	5.0	4.8
Jawaharlal Nehru	India	Far East	36	34	0.8%	4.5	4.5	4.5	4.1	4.3	4.3
Singapore	Singapore	Far East	2	2	0.6%	30.9	30.9	33.9	32.6	31.7	29.9
NW Seaport Alliance	USA	North America	42	43	0.2%	3.6	3.5	3.4	3.5	3.5	3.6
Keihin Ports	Japan	Far East	20	20	-0.1%	7.6	7.5	7.9	7.8	7.9	7.6
Hamburg	Germany	Europe	17	18	-0.2%	8.9	8.8	9.7	9.3	8.9	9.0
Jeddah	Suadi Arabia	Middle East	40	36	-0.3%	4.0	4.2	4.2	4.6	4.7	4.0
Lianyungun	China	Far East	33	30	-0.6%	4.7	5.0	5.0	5.5	5.0	4.9
Colon	Panama	South America	46	42	-0.7%	3.3	3.6	3.3	3.4	3.5	3.4
Bremen/Bremerhaven	Germany	Europe	27	25	-1.5%	5.5	5.5	5.8	5.8	6.1	5.9
Balboa	Panama	South America	50	46	-1.5%	3.0	3.3	3.5	3.2	3.3	3.2
Tanjung Priok, Jakarta	Indonesia	Far East	30	27	-2.1%	5.0	5.2	5.8	5.5	5.5	5.5
Hong Kong, S.A.R.	China	Far East	5	5	-4.3%	19.6	20.1	22.2	22.4	23.1	24.4

As shown in Chapter 3, many scholarly publications link port growth with economic and trade growth. The IMF (World Economic Outlook Database, 2014) reported stagnant growth in the advanced world, including the USA, the EU and Japan as was shown in Figure 4.2. From Figure 4.2 and Table 4.2 several linkages can be made. First, the ports of the developed world are showing decline and mirror the slower growth highlighted by the IMF. This is seen at the UK and USA ports, and also some European ports on the Top 50 list. Secondly, the growth in the developing regions of the Far East has been leading to a significant number of port volume increases. Six of the fastest growing ports were in the Top 20 in 2016 and these ports were already considerable in size. Analysing the complete Top 50 list, the port volume growth for the Far East over the five years was calculated at 3.3% per annum. For the EU, the five-year growth was 1.8% per annum, but if the two fast growing ports from Spain and Malta in Table 4.2 are excluded, this drops to 1.3%. The North American ports on the Top 50 list showed a 2.3% growth per annum.

Although there is far more detail to this than is evident from Table 4.2, the linkage between trade and economic growth and port growth seems to be a fair one. The growth is, however, driven by commodities traded and the detail of container content could provide more detailed knowledge and insight for accurate forecasting. The effect of growth and decline in ports not listed in the Top 50, is hidden from this high-level analysis, and should not be ignored. One example of this is the Port of Durban. This is the only port listed in one of the fastest growing economic regions, sub-Saharan Africa, but the port is not listed and dropped off the Top 50 list a few years ago from being previously listed under the stagnant ports. The effect of multiple other fast growing ports in sub-Saharan Africa is thus hidden, because they are too small to even make the Top 50 list (Salisbury, 2015). Some of these port capacities will be described in section 4.4.

4.3.2 Trends in ship size increases

When one compares the three cargo ship types, the network of container ships is densely clustered with a large number of journeys per link; the liquid bulk carrier network is less clustered and has fewer journeys per link, with the dry bulk network having the fewest journeys per link and lowest clustering. Different ship types use essentially the same ports, but different connections. Container ships typically follow set schedules, visiting several ports in a fixed sequence along the way, whereas dry bulk carriers appear less predictable as they frequently change their routes on short notice depending on the current supply and demand of the goods they carry.

As of 1 Jan 2017 the global container ship fleet had capacity of 20.3 million TEUs with another 3.2 million TEUs on order (Statista, 2017). In terms of market share, Maersk Line continues to dominate with 18.4%, based on its fleet, including order book, of roughly 4.2m TEUs, followed by MSC with 13.5%, on around 3.1m TEUs, while CMA CGM's capacity of approximately 2.4m TEUs gives it a 10.4% share (The Loadstar, 2017).

The average global fleet size of container ships has been increasing notably from one year to another. This is evident from the changes in the fleet composition, indicated by current average and maximum ship sizes. Table 4.3 shows the status that as of Jan 2016, there are 5 249 ships with a total capacity of about 19.8 million TEUs; this is 71% more than the global fleet size at the end of 2007 (Drewry, 2008). The last few years have seen a spurt of 10 000+ TEU ships, which contribute a significant share of 13% to the total capacity. The cellular fleet increased by 8.5% in 2015 (Port Strategy, 2017).

Table 4.3: World cellular container ship fleet by size range (Clarkson Research, 2016)

CLASS (TEU Range)	Average Size/dimensions/age				In Service		
	Length (metres)	Beam (metres)	Draft (metres)	Age (years)	Ships	Total TEUs	Average TEUs
Feeder (100-999)	132	21.1	7.5	16.2	1 070	648 809	606
Handy +(1,000-2,999)	179	27.6	10.0	12.1	1 883	3 374 966	1 792
Sub-Panamax(2,000-2,999)	224	32.8	12.3	12.1			
Panamax (3,000 & Over)	286	34.6	13.5	10.5	844	3 549 442	4 206
Post-Panamax (>8,000)	302	42.7	14.7	9.2	680	3 916 853	5 760
Post-Panamax (8,000 - 11,999)	354	48.7	15.6	5.8	533	4 788 135	8 983
Post-Panamax (12,000 & over)	403	55.4	16.6	3.2	239	3 456 960	14 464

Drewry (South Africa Ports Vessel Size Analysis, 2013) indicated in their ship size analysis report that the average and maximum ship sizes have increased notably between 2007 and 2013. While the average ship size has increased by about 43%, the largest ship to have been built in a particular year has risen over 74% to 16 000 TEU from 9 200 TEU. With rapid advancements in size of the largest new builds, there have also been changes in ship design with an aim to maximise carrying capacity with as little increase in ship dimensions as possible, to more efficiently accommodate the ships at ports. The design innovation at play is evident on studying the marginally low increase in dimensions between ship size of 16 000 TEU and the 18 000 TEU ships, which were due for delivery in 2013. Drewry has used similar increments to project dimensions of ships beyond 18 000 TEU.

China Shipping Container Line's (CSCL) has ordered five ships of 18 400 TEU capacity at the Hyundai Heavy Industries shipyard in Korea for delivery in 2014 to 2015. Moreover, OOCL ordered the *OOCL Hong Kong* with 21 000 TEU capacity, delivered in May 2017 (OOCL, 2017).

With bunker consumption accounting for the single largest deep-sea shipping cost component, the incremental savings from larger new builds are crucial to have a competitive advantage, which in turn is driving the ordering spree. However, excess supply is creating other problems such as eroding ocean freight rates and is likely to arrest a sustained growth in new builds.

4.3.2.1 Implications of ship size forecast on South African ports

The largest container ship ever to visit a South African port was the MSC Sola in July 2012. This ship weighed 131 771 tons, is 355 metres long, and is capable of carrying 11 660 TEUs when fully laden. The MSC Sola has a maximum draught of 15 metres and a beam of 46 metres (Containership Info, 2017). Prior to the completion of Transnet's R300 million project to widen and deepen the entrance to the Port of Durban in 2010, she would have been unable to enter. The harbour entrance was dredged only to a depth of 12.8 metres before this project commenced (News24, 2012).

Drewry (2013) derived a South African port and ship size forecast from global forecasts. In their ship size forecast, Drewry have assumed port constraints to exist in initial years only, as the purpose of their forecast is to see whether or not new port infrastructure will be required in the future. This only had an influence on the maximum ship size. The following South African ports covered in the Drewry report currently handle or are forecast to handle containers by 2042 or beyond: Richards Bay, Durban, East London, Ngqura, Port Elizabeth, Cape Town and Saldanha. Table 4.4 provides average and maximum dimensions of the expected fleet to visit the South African ports in the long term.

Table 4.4: South Africa: Average and maximum ship dimensions (Drewry Maritime Advisors, 2013)

Year	Average capacity (TEU)	Average (metres)			Max capacity (TEU)	Maximum (metres)		
		Beam	LOA	Draft		Beam	LOA	Draft
2012	3,824	32.2	228	11	11,660	46	355.5	15
2015	4,307	32.2	259.8	12.3	12,000	48.2	366	15.5
2020	5,264	39.8	278.9	13	13,890	51.2	366.5	15.8
2025	6,357	40	294.7	14	16,100	53.6	395.0	16
2030	7,685	42.8	303.9	14.2	16,920	54	399	16.1
2035	9,266	44.4	332.6	14.5	17,790	59	400	16.3
2042	12,004	48.2	366	15.5	20,430	63.2	405	16.5

This provides an indication of the dimensions that port entrance, berth, draft and quay wall infrastructure might have to adhere to in the future. No distinction on ship size forecast is made between the different ports.

It is likely that the dimensions of the ships provided in Table 4.4 will decrease as the existing fleet is replaced by new builds. Similar design changes are notable in recent new builds and orders of around 4 000 TEU ships designed with a wider beam and much smaller length than before specifically to serve trades like West Africa and East Coast South America, where port infrastructure is inadequate to handle existing ships of the same carrying capacity. Since these constraints do not exist for the ports under review for the Drewry study, the ship dimension of all ships, which exist in the fleet, are provided based on typical dimensions of the existing fleet.

4.3.3 Trends in handling technology

The key technological trend which is driving the container industry, is the rapid development of ship sizes – mainly as a result of economies of scale afforded by larger ships, but also due to changes in shipping lanes such as the expansion of the Panama Canal. The use of larger ships in trade lanes places a greater emphasis on the port or terminal to be able to efficiently meet the demand for higher container volumes moving to/from larger ships. The more efficient a container-handling facility is for these larger ships, the more attractive the facility will be to the shipping line. As larger ships enter the primary Asia-Europe and Transpacific container trade routes, existing ships are moved into other trade routes, notably North–South services such as to/from Latin America and to/from South Africa.

As larger ships move into these different routes, port infrastructure will need to accommodate these ships. With larger tonnage likely to continue entering many major East–West trades, the ability of key ports to continue to offer efficient terminal operations is going to increase. The goals of terminal development are often focused on minimising ship turnaround time due to the cost of keeping a container ship in a port. The more efficient the terminal operation can be, the quicker the ship can return to sea, or, as an absolute minimum, maintain its sailing schedule. Ports and terminals attempt to minimise the length of time a ship is at berth in various ways, including:

- Deploying more quay cranes per ship; however, this is constrained by the length of the ship and the minimum distance required between cranes;
- Improving the handling rate of the individual cranes by increasing the speeds and semi-automation features of the cranes;
- Improving reliability and maintainability of the cranes so as to minimise the amount of reworks;
- Training and using skilled operators to man the cranes;
- Providing efficient yard handling and horizontal transportation systems for the loading and discharging/unloading operations;
- Deploying automation;
- Ship loading/discharge planning.

The ability of any terminal to offer improved operating efficiencies is of great importance to its shipping line customers. The use of automation and technology to help achieve this goal is, therefore, a credible option that will be of interest to any potential shipping line caller to a port or terminal, because of the ability to maintain schedule integrity and maximise the number of containers that can be discharged/loaded to the ship while it remains at the berth.

Terminal operators are increasingly turning to automation. By employing automated stacking cranes, rubber-tyred gantries, or rail-mounted gantry cranes on steel wheels, terminal operators not only take advantage of electric power, but improve operational efficiency through automated equipment. Increased terminal efficiencies allow cargo to be handled with fewer air emissions. Automated terminals require a significant amount of infrastructure; however, the reductions realised in fuel and labour savings can offset the infrastructure costs, allowing the port to meet overall business objectives.

The implications for ports/terminals designed for Ultra Large Container Ships (ULCS) of 22 000 TEUs are that larger shore-side gantry cranes, with an outreach of 72 metres and a lift height of 52 metres above the quay are needed. The distance between crane's legs may also need to be increased from 30 metres to 35 metres. This can be problematic as the legs operate on rails built into the quay, making upgrading subject to spatial and underpinning constraints. Some of the challenges of larger cranes include stiffness, weight, corner loads, wind loads, increased power and operational issues including visibility, handling speeds and performance. Single ULCS can deploy up to 10 jumbo cranes, each with an outreach of 23 containers wide. (Some ports already operate cranes 25 containers wide.)

The world's largest crane manufacturer is the Chinese firm ZPMC, which holds approximately 75% of the market share and is continually updating designs. There are, however, limitations to how many cranes can be deployed per ship due to the finite width of Ship to Shore (STS) cranes, and increasingly wider ships do not necessarily permit more cranes to be deployed unless an indented berth concept is adopted. Ceres Paragon's indented berth terminal in Amsterdam allows the unloading of a container ship from both sides of the ship, unlike traditional berths that utilise one side only. STS cranes are used operating from either side of a U-shaped berth. APM Terminals in Rotterdam is, however, busy extending this concept by considering gantry cranes. These cranes are narrower and can be used to work more closely together, thereby increasing the number of cranes to be deployed per ship. In this way adjacent rows can be worked, whereas present STS cranes are too wide to allow this (APM Terminals, 2017).

4.3.4 Trade routes

The global maritime transport network mostly takes the form of a hub-and-spoke system where hub ports along the major route (equatorial via the Suez and Panama canals) carry the majority of the trade and secondary routes feed cargo to ports north and south of the major route. Figure 4.8 shows the world' s busiest shipping routes as being in the northern hemisphere.

Table 4.5 indicates container trade (which is the busiest trade) along the major routes (also known as 'superhighway' or 'Circum Equatorial Route'). (This table is a combination of values extracted from three different reports.) The largest volumes are experienced from Asia to North America (16.8 million TEUs). This route is also the fastest growing route by far over the 6 years at 8 % per annum.

The hub-and-spoke system is likely to become even further entrenched along with the expansion of the Panama Canal. It is possible that this expansion could create an ever larger superhighway along the equator and thus expand the opportunities for transhipment, including interlining along pendulum routes.

The pendulum routes most important to South Africa are the 'transoceanic pendulum' routes. These routes are born out of a critical mass in certain regions and are emerging now. They (i) traverse the oceans from Asia-America-Europe in the north, and (ii) traverse the oceans connecting Asia to South Africa and on to Brazil in the south. The latter will become increasingly important as BRICS trade increases.

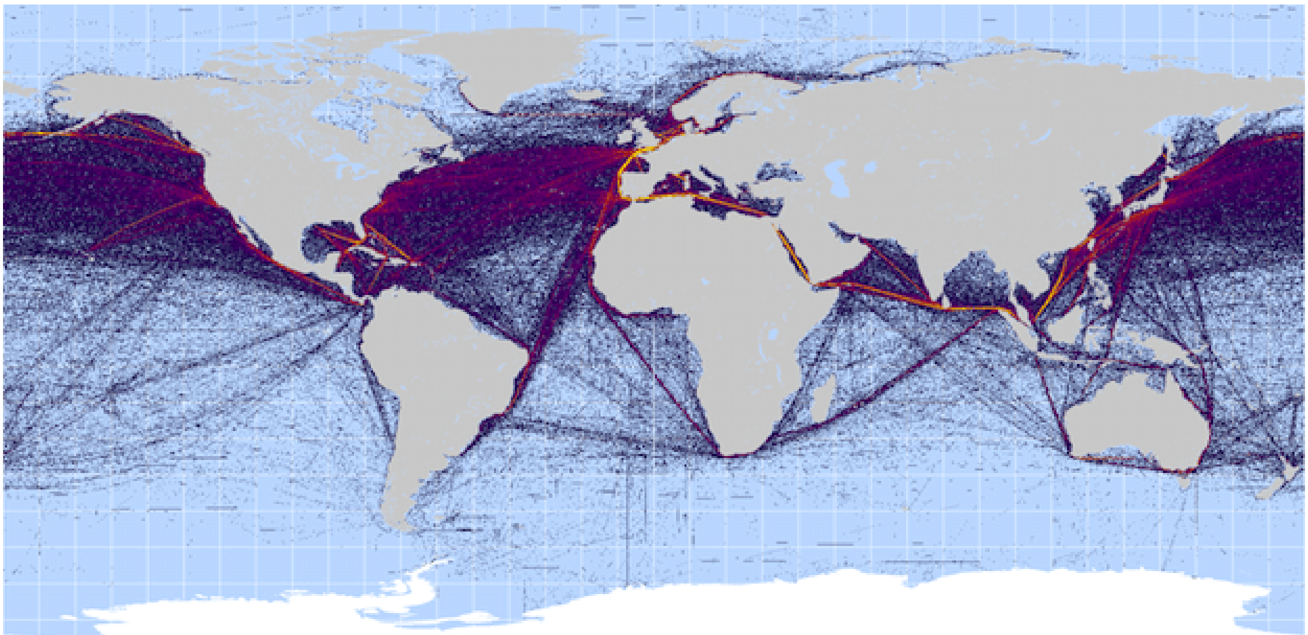

Figure 4.8: The world's busiest shipping routes (European Commission Global Environment Monitoring Unit, 2012)

Figure 4.9 indicates that global trade in the South is increasing as can be seen in container numbers per country as a percentage of total volumes. The USA's share of global container trade has fallen from 22.9% in 1979 to only 7.0% in 2011. The fall for the United Kingdom was from 6.9% to 1.5%. Brazil and India together remain a low total share (3.0%), but this is up from 0.7% in 1979. South Africa's share over the same period dropped from 1.4% to 0.8%, where it has remained constant.

It is unlikely, however, that South-South trade will reach the quantities of the 'superhighway'. There is no Southern Hemisphere equivalent of the Container Super Highway. South-South trade volumes do not (and will not for many years to come) warrant such a service. As a 'Hub for Africa', South African ports are less favourably placed than Algecires (Spain) and Salala (Gulf of Aden), which are both on the Container Super Highway. Escalation of the piracy off the coast of Somalia, or congestion of the Suez Canal could force container operators to route via the Cape of Good Hope, but this would be transitory.

Table 4.5: Estimated containerised cargo flows on major East–West container trade routes, (Millions of TEUs and percentage change) (UNCTAD, 2012), (UNCTAD, 2015) (UNCTAD, 2016)

Year	Transpacific		Europe Asia		Transatlantic	
	Asia- North America	North America - Asia	Asia - Europe	Europe- Asia	Europe - North America	North America - Europe
2009	10.6	6.1	11.5	5.5	2.8	2.5
2010	12.8	6.0	13.5	5.6	3.1	2.8
2011	12.7	6.0	14.1	6.2	3.4	2.8
2012	13.7	6.4	14.2	6.3	3.5	2.8
2013	14.6	6.9	14.9	6.6	3.8	2.7
2014	15.8	7.4	15.2	6.8	3.9	2.8
2015	16.8	7.2	14.9	6.8	4.1	2.7
% change 2009- 2015	8.0%	2.8%	4.4%	3.6%	6.6%	1.3%

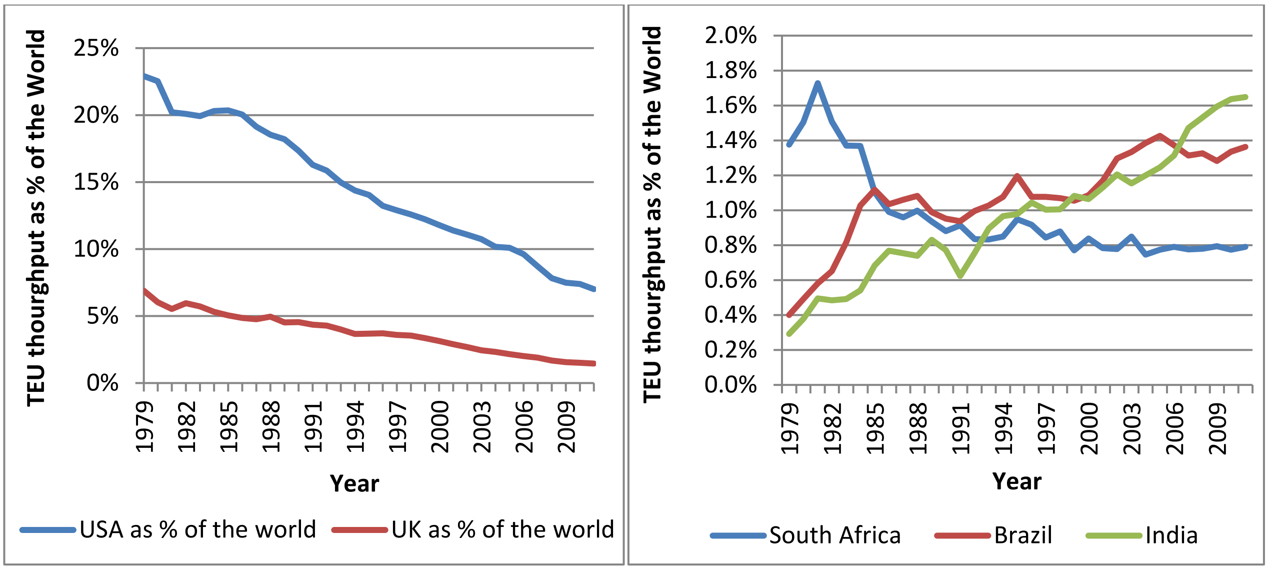

Figure 4.9: Shifting trades (1979–2012) (Sooredoo, 2013)

4.4 Port networks and competitiveness – sub-Saharan Africa

4.4.1 Port clustering

The Liner Shipping Connectivity Index captures how well countries are connected to global shipping networks. It is computed by the United Nations Conference on Trade and Development (UNCTAD, 2016) based on five components of the maritime transport sector: number of ships, their container-carrying capacity, maximum ship size, number of services, and number of companies that deploy container ships in a country's ports. The higher the index, the better connected the country is.

Global shipping connectivity is dominated by the East Asian and South Asian ports of China (156), Hong Kong (117), Singapore (113), Korea (102) and Malaysia (100). These are followed by the United States of America and European ports. Within the top 25 countries are the Middle East and North African countries of the UAE, Saudi Arabia, Egypt and Morocco. Much further down the list lies the first South American country (Brazil, index of 38.5) and the first Southern African country (South Africa, index of 36.8). The most connected port countries are mostly Northern Hemisphere or Far East countries. This trend follows the container port traffic trends.

A study by Kaluza et al. (2010) goes further to identify 'port communities', which are groups of ports with many links within the groups, but few links between different groups. A port with a high betweenness score could potentially play a 'broker' role between different clusters in the network. These ports are ideal locations for transhipment. South Africa is within the top 50 ports for betweenness and one of only two ports in the southern hemisphere. In-depth research from Notteboom (2012) identifies South Africa, particularly the Port of Ngqura, as an ideal broker for the West Africa–Oceania, West Africa–East Africa and South America East Coast–East Africa trade lanes, provided the appropriate infrastructure is provided and port efficiency is globally competitive.

Port development in other coastal SADC countries and the development of efficient SADC inland corridors could soon change the role South African ports play in the SADC freight economy. It is imperative that South Africa critically evaluates its changing neighbourly role within SADC as well as its role as primary connector of SADC freight to world markets.

4.4.2 Regional port development

This section highlights the potential threats to South Africa from regional port development and the investment by other African countries into port-related infrastructure. Figure 4.10 is indicative of sub-Saharan African ports by size and provides a spatial representation of port competition on the continent. The port volumes indicated are however not for containers only, but include dry bulk, liquid bulk and general freight. What this figure also highlights, however, is the competitive advantage of South African ports due to the volume of freight attracted and their multimodal connectivity to the hinterland. This connectivity is virtually unrivalled on the continent.

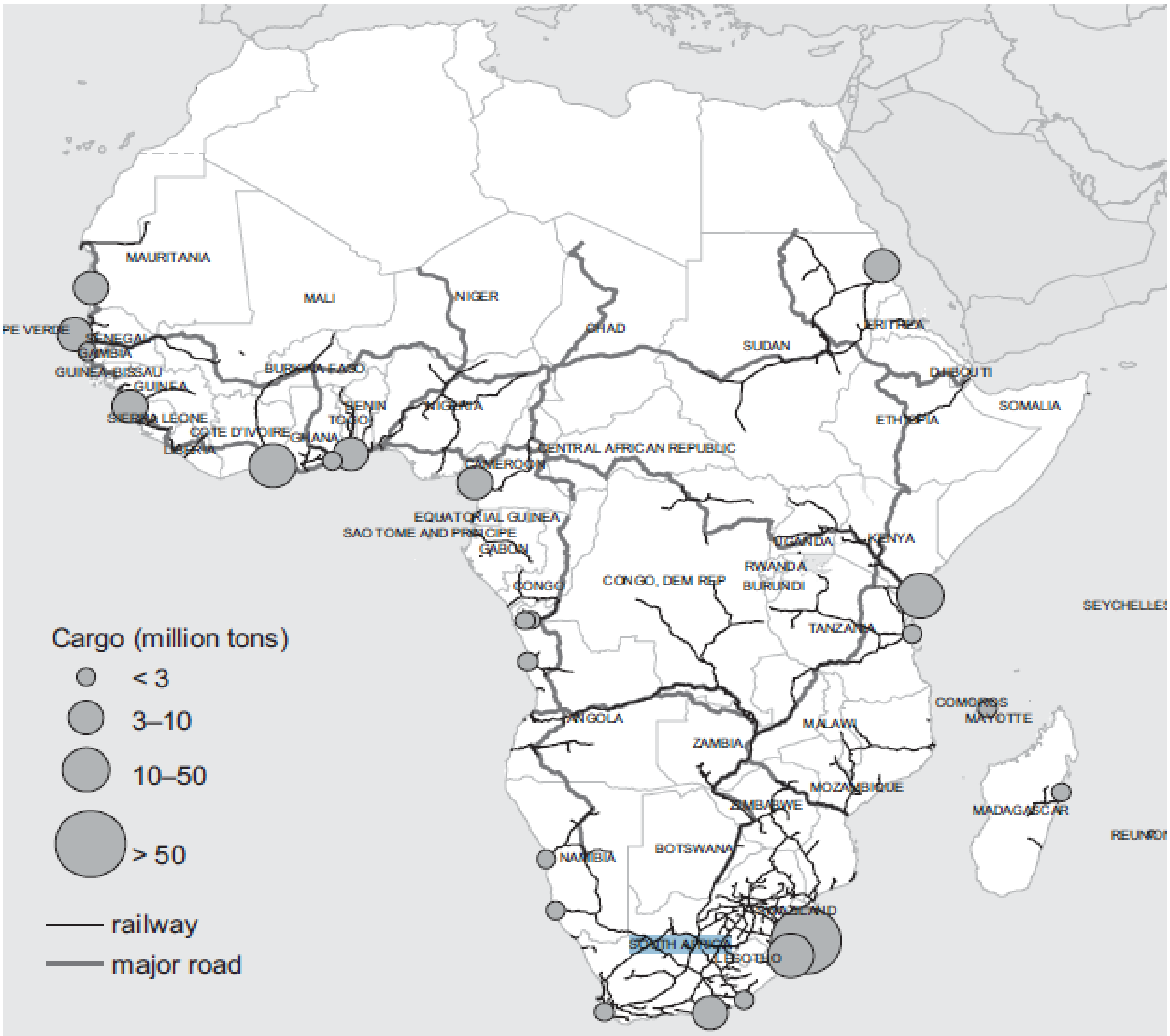

Figure 4.10: Ports of sub-Saharan Africa (Foster & Briceño-Garmendia, 2009)

The primary African ports which could have a potential impact on South African port volumes are those in sub-Saharan Africa, specifically within the SADC region. SADC (2012) lists 19 ports which it considers to be of regional importance. The SADC study has identified the following major port nodes (and associated corridors) as of primary importance to the Southern African transport network:

- Nacala;
- Beira;
- Maputo;
- Durban;

- Walvis Bay;
- Luanda.

It is of interest to note that three of the ports are located in Mozambique.

Total port traffic through these six ports is projected to increase from 92 million tonnes in 2009 to 500 million tonnes in 2027. A major increase in traffic is from landlocked countries where traffic is expected to increase to more than 100 million tonnes per annum over the next 30 years. This will create major infrastructure capacity problems. Furthermore, existing and ongoing port projects are not expected to provide the required capacity, particularly with regard to container capacity. Future port capacity is expected to be complicated by the development of large mineral projects that will require new ports or port expansions (as well as the associated rail connections). SADC (2012) argues that port development programmes should be put in place immediately in most regions, to ensure that enough port capacity will be provided on time.

South African ports are providing a valuable service to countries that cannot otherwise be reached by overseas trade partners. If infrastructure developments in terms of ports and corridor development happen, these ports and corridors could be in competition with South African ports and road and rail corridors into the hinterland (Gauteng and further north). Notteboom (Port regionalization: towards a new phase in port development, 2005) argued that this would only be practical if the corridor and the port infrastructure development to the hinterland is done in synchronisation. Large port infrastructure investment and complementary corridors from the ports of Walvis Bay and Maputo are already competing against South African ports for South African freight. More recently the Port of Beira also increased in container volumes from 105 700 TEUs in 2010 to 218 700 TEUs in 2014, surpassing the container volumes reported by the Port of Maputo (Hellenic Shipping News, 2018). These volumes prove to be significant and could start to impact on South African port container volumes.

4.4.2.1 Implications for containers

The past decade has seen large changes in the global container industry: global throughput and the number of container cranes have doubled. Chinese ports have gained the most market share, while African ports' share of the market has remained stable. Egypt was ranked in first place in terms of total container throughput in Africa in terms of 2011 figures (Sooredoo, 2013). It had a total throughput of 6.35 million TEUs. South Africa was second with 4.6 million TEUs and the closest SADC country was Tanzania with 0.57 million TEUs. The top ports in Africa are Port Said (1st) and the Port of Durban (2nd) with the Port of Cape Town in 9th place. No other SADC ports feature in the top 15. The greatest growth in container traffic is in the North African ports, which benefit from transhipments from the Mediterranean region (i.e. Tangier), while slowest growth is seen in the southern region (Sooredoo, 2013).

Transnet Port Terminals (Durban Container Terminal, 2017) report Durban Container Terminal to have a capacity of 3.6 million TEUs. Container terminal expansions planned for Walvis Bay will increase this port capacity from 375 000 TEUs to 650 000 TEUs to be complete in 2017 (Port Finance International, 2017). This would increase their capacity from 10% to 18% of the Port of Durban’s container capacity. The Port of Maputo is also in the process of increasing its capacity from 150 000 TEUs to 300 000 TEUs (Port of Maputo, 2017). This would increase Maputo’s capacity from 4.2% to 8.3% of the Port of Durban’s container capacity. The additional capacity in build is not expected to erode Transnet volumes significantly, but rather complement the Transnet port system since the largest portion of Transnet traffic is based on the local South African market. For transit traffic (to countries north of the SA border) these ports will however provide an alternative. In order to compete effectively for transit traffic, the timeliness, reliability and overall cost of the entire transport chain will eventually determine the gateway potential of a port. In addition, traffic through Maputo has benefited in recent years as a result of congestion in South African ports, and furthermore, Maputo can be seen as the natural port of the Gauteng, Limpopo and Mpumalanga regions. As such, this port will always provide competition to the Port of Durban (and other ports), especially if its operations are efficiently run.

Walvis Bay's main threat would be for the highly volatile transhipment trade. The degree to which transhipment is tied to a particular port or terminal is considerably looser than for local import/export cargo flows. Although the location of a particular terminal may favour a transhipment hinterland, the geographic concentration of major regional ports may provide several viable choices to the shipping line. Both Ho et al. (2008) and Notteboom (2010) argued that the following elements are important considerations in the choice of a hub port: location, total cost, service levels, water depth/accessibility, feeder links, existing business structure, and available dedicated capacity. Walvis Bay's planned port expansions (and good service levels) may therefore erode transhipment volumes for TNPA ports.

4.4.3 East–West corridor development

Port competitiveness has not been a factor to consider due to the Transnet controlled port system in South Africa and relatively small and inefficient competing ports (Walvis Bay and Maputo). However, significant international port developments in sub-Saharan African countries (Angola, Mozambique, Kenya, Tanzania, etc.) cannot be ignored any longer. Firstly, due to freight owners shipping to and from these countries and other landlocked countries via the Port of Durban port as their preferred point of entry. Secondly, these new port developments could in the medium to long term have a significantly negative impact on transhipped and coastwise container volumes utilising SA port infrastructure.

The initial focus for sub-Saharan trade was always to move as many raw materials out of the sub-continent to beneficiation facilities overseas as possible. This approach, combined with the relative maturity of South Africa when compared to other countries, led to a distinct North–South corridor development from the middle of the subcontinent (the southern parts of the Democratic Republic of the Congo) through Malawi, Zambia, Zimbabwe and Botswana to South Africa's Eastern seaboard. This trend was entrenched in the post-war period, when counter-intuitively, South Africa's global isolation, continued involvement in the destabilisation of the region and civil wars, stunted SADC developments and the only real option to reach export markets remained to be through South Africa.

This position changed over the last two decades, and it was always expected that these changes would have a major impact on corridor and port development. South Africa has adopted a more open and supportive role in SADC, most SADC countries now grow faster than South Africa (albeit from a very low base) and these countries are finally in the position to attract major infrastructure investments. These investments are leading to the development of East–West corridors, shown in Figure 4.11, as an alternative to the North–South configuration (which favoured South African ports). These East–West developments also follow the natural development route of South to North, in line with the development capabilities of the subcontinent. The most Southern and mature link is Maputo–Walvis Bay, followed by the second more Northern link, i.e. Lobito–Nacala. Preliminary considerations about the third link between Mwambani and Banana have emerged. Mwambani is between Dar-es-Salaam and Mombasa in the East and in the Democratic Republic of the Congo on the Western Seaboard of Africa.

The Maputo–Walvis Bay corridor has road links in a good condition and well-established rail links between Lobatse and Maputo and between Gobabis and Walvis Bay, a sizeable portion of the corridor. The corridor's remaining challenges (although the Trans-Kalahari rail link is often discussed) are more institutional, such as fixing border crossing delays and developing joint development plans between South Africa, Botswana and Namibia. Notably, though, these forums are already established and new initiatives are already on the table. The ports of Walvis Bay and Maputo are receiving funding, in line with these developments and warrants specific focus in South African port strategy development.

The Nacala–Lobito corridor links the Western Seaboard in the middle of Angola with the Copper Belt of the DRC and northern Zambia and runs through Malawi to the middle of Mozambique on the Eastern Seaboard. Rehabilitation is required for the Lobito rail link linking the port with the DRC/Zambia Copperbelt and improvement of the road infrastructure. This is linked to the repair and development of mines following the extended conflict in the DRC, which has hampered development. The trunk routes to Nacala on the eastern side currently serve low traffic volumes, but demand is increasing as Nacala is receiving major investments to develop the port. Most road sections are unpaved and/or have high roughness levels; traffic at the port is expected to increase rapidly beyond its current capacity. Vale completed the construction of a 150 km heavy haul coal rail link from Moatize in Mozambique to Malawi to open up coal exports through Nacala.

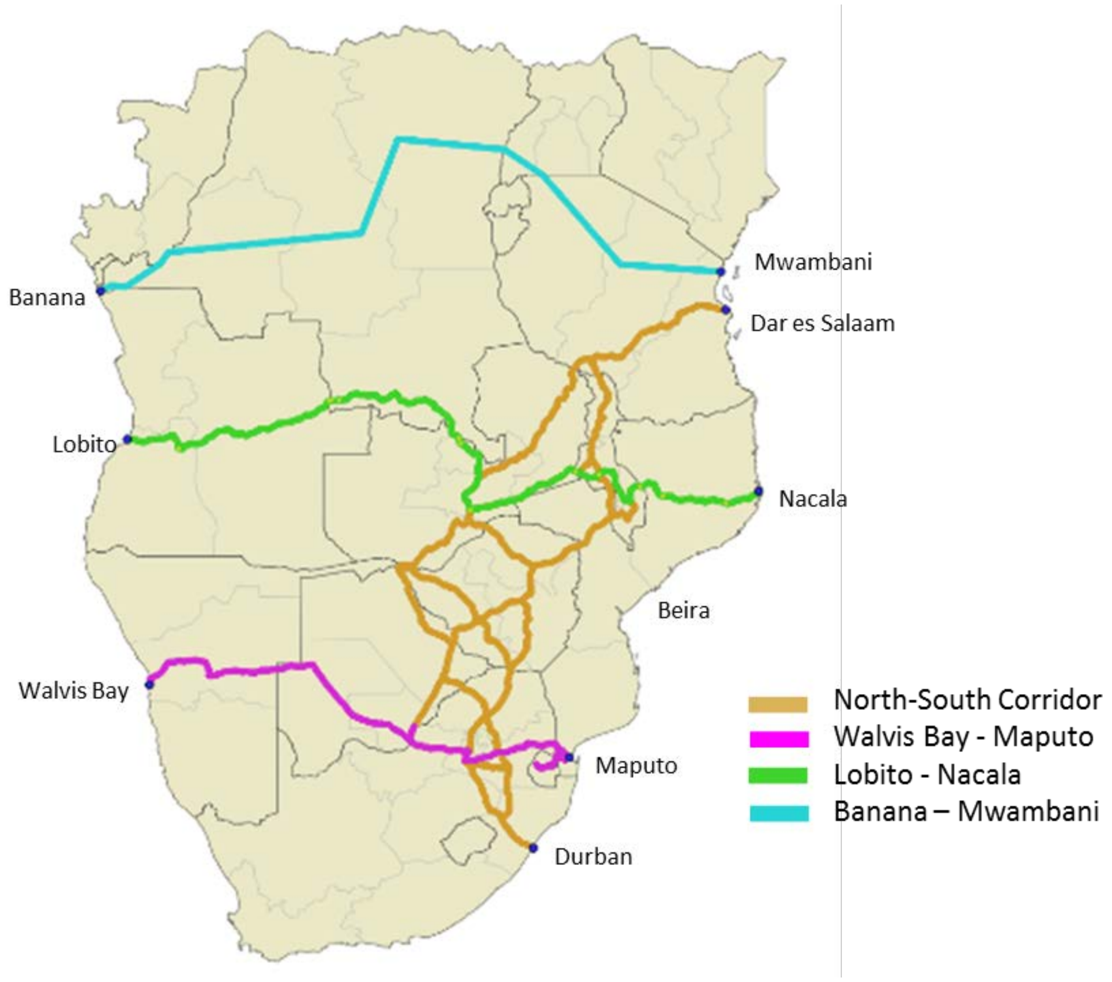

Figure 4.11: East–West corridor development routes in sub-Saharan Africa

The Mwambani-Banana rail and port corridor plans seek to integrate cross-border logistics and bulk freight rail transportation services from the Indian Ocean Deep-sea Port of Mwambani in Tanzania, across East and Central Africa to the Atlantic Ocean Deep-sea Port of Banana in the DRC. This should establish an economic corridor across the region. The plan is new, and a high level business plan was only developed in 2012, but the thoughts around the corridor fit the natural development of East–West corridors and the consideration of even more ports north of South Africa in strategy development.

These corridor developments could potentially shift traded container freight movements away from the Port of Durban to other ports. If port capacity is developed and port efficiencies achieved, shipping lines will include these ports on the east and west coast to their pendulum routes and reduce direct and transhipped containers away from South African ports. This is not a given, but progress with these proposed investments need to be closely monitored.

4.5 Design requirements identified in this chapter

The model design requirements identified in this chapter are listed in Table 4.6. Most of these supply-side and demand-side factors can be classified as Attention points (A) that will need to be frequently monitored to assess the impact of these aspects on especially full marine deep-sea and transhipped containers.

Table 4.6: Design requirements identified in Chapter 4 (numbering continued from Table 3.6)

Req. ID	Requirement	Motivation	Quay wall extent
F2	Percentage containerisation	Introduced in Chapter 2, repeated in Chapter 3. Globally the rise in containerisation is levelling off at 65–70% with some commodities still shifting sharply. With content knowledge unknown, two-thirds of port forecasts are 'commodity blind'.	Marine deep-sea
F5 (linked to U2)	Container physical types	Introduced in Chapter 2 (as a User requirement). Ship size increases and pressure on port efficiencies leads to preference towards 40 foot containers. This dynamic also has an impact on the berth infrastructure required and needs to be incorporated into the demand.	Marine deep-sea, Transhipped, Empty
A2	Port hinterland trade patterns	Introduced in Chapter 3. Global shifts in trade patterns between developed and developing economies would change the demand for container movements to the hinterland of the South African port system. This change involves both South African trade partners and hinterland neighbours using South African ports.	Marine deep-sea
A3	Hinterland economic structure	Introduced in Chapter 3. Population growth and affluence lead to hinterland consumption growth. GDP growth and shifts in economic sectors will influence a country's demand for transport requirements and also container content shifts.	Marine deep-sea, Transhipped
A7	Empty percentage	It is notable that globally the empty containers as a percentage of full containers have remained stable between 15–20% for the last decade.	Empty

Req. ID	Requirement	Motivation	Quay wall extent
A8	Transhipment percentage	It is notable that globally the transhipment containers as a percentage of full containers have remained stable around 25% for the last 7 years.	Transhipped
A9	Port capacity and efficiency	African container ports and terminals are small compared to international standards with the Port of Durban falling off the Top 50 container port list a few years ago. Other sub-Saharan Africa ports are even smaller in comparison. This needs to be monitored for South African ports and all potential competing ports that could service the sub-Saharan Africa hinterland.	Marine deep-sea, Transhipped, Empty
A10	Container ship size	Ship sizes are ever-increasing with smaller ships being scrapped. Larger ships are moved to lower volume routes, constantly impacting on port and terminal dimensional requirements and ship-to-shore infrastructure requirements.	Marine deep-sea, Transhipped, Empty
A11	Shipping line route decisions	Routes will change as dominant economies change and more trade volumes are available for shipping lines to exploit. Africa is showing significant economic growth potential, and this could draw significant investments in port and corridor infrastructure that draws volumes and shipping routes away from South African ports.	Transhipped
A12	Global shipping fleet	The balance between carrier types (container, dry bulk, liquid bulk, break-bulk, reefer bulk, RORO ships) would determine the requirement for container movements. If no more bulk reefer vessels exist, it means that perishable items would always be 100% containerised.	Marine deep-sea, Transhipped
A13	Global physical container populations	The physical container types available globally are changing towards more 40 foot containers being manufactured. Thus the container types being available will be dictated by international trends.	Marine deep-sea, Transhipped, Empty

4.6 Conclusion

This chapter highlighted various aspects (or parameters) of container demand and container supply to understand these two push and pull influences in the global shipping context. These parameters are expected to have a significant influence on container trade and support the inclusion of these parameters in a container demand forecasting model.

These elements are important drivers of the sectoral and geographically disaggregated economic forecast model upon which South Africa's FDM is built. While the detail of the economic forecasting model is excluded from the scope of this dissertation, it is a core input into the container demand model via the FDM's commodity flows. Close interaction between the economic forecasting model and the container demand model is imperative and already established.

With specific reference to data inputs for the container model, it is important to:

- Estimate the current containerisation propensities of South Africa's imports and exports, and determine a potential future ceiling for containerisation per commodity group to determine (so-called substitution growth as per Rodrigue and Notteboom (2015));
- Utilise the commodity-level freight flow forecasts to establish opportunities for organic growth (Rodrigue & Notteboom, 2015) in containerisation (at the level of trade growth of containerisable commodities).

Global patterns have been established for empty and transhipment containers being measured as a percentage of the full containers. These patterns and trends can be used per port to model these containers if no other models with higher accuracy can be established.

The next chapter analyses available industry datasets to further determine inputs for the container demand forecasting model.

5. Discussion and analysis of industry datasets

5.1 Introduction

This chapter aims to provide an objective discussion of the quantitative datasets used and the outcomes generated during the analyses of these datasets. They were obtained from industry partners by the researcher as part of a project team.

The initial research for Transnet started over a decade ago with the primary objective to understand the complete surface freight flow market of South Africa. This was done to provide Transnet with an objective input into various business strategies, i.e. focused marketing of rail services and infrastructure capacity planning, amongst others. The journey started with detailed TFR data combined with input-output economic data to understand the freight flow market. This data was combined with traffic counts and road surveys to enhance the actual rail data with road surface freight flows. The research team recognised that the changing world economic structure would dictate growth in containers; however, they realised that rail market share for containers was very low and thus limited in the level of detail it provided to understand containers. It thus became important to understand the contents of containers.

TNPA seemed like the obvious good source for this data. TNPA did not capture the container content data and at that stage their commodity groupings were not SIC based. SARS customs data seemed like the next logical step, but their datasets had almost too much detail and too many discrepancies. This led the research team to shipping line data as the next opportunity, but this was initially very difficult to obtain. The shipping line data was laborious to analyse, but gave the team great insights and could be seen as a major breakthrough in this research journey.

For the proposed container model in this dissertation, the shipping line data formed the core dataset. It is the only dataset that can provide detailed container content data for the South African quay wall containers at this stage. Since the shipping line dataset is a sample and thus not complete; the TNPA container data was required to obtain a complete picture of all containers over the quay wall. These two datasets were enhanced and validated with other data sources from industry and government agencies as and when necessary. Table 5.1 provides an overview of the different industry datasets used and the purpose they fulfilled in this dissertation.

Table 5.1: Datasets used and their purpose for this dissertation

Data Source	Purpose of the dataset
Shipping Line	Core dataset providing content information for a growing sample size of full quay wall containers, per port, per international origin/destination.
TNPA Containers	Provide the number of containers across the quay wall into and out of the country per port split into full, empty, transhipped and coastwise containers
TNPA Bulk	Provide volume of non-containerised commodities
SARS data	Validation of imported and exported volumes per commodity per port or border post
TFR data	Surface flows of container numbers and volumes of bulk commodities connected to ports are used to validate imported and exported volumes per commodity per port
Trade industry bodies	Validation of imported and exported volumes per commodity per port
Economist reports	Validation of imported and exported volumes per commodity per port
Government departments	Validation of imported and exported volumes per commodity per port

These datasets were sourced for various years to obtain sufficient detail to ensure that once-off events could be identified and removed from the data so as to not disturb the validity of the datasets as input elements. Table 5.2 provides an overview of the range of secondary datasets obtained from the various sources and the years these data were made available.

Table 5.2: Secondary datasets and years available

Data Source	2009	2010	2011	2012	2013	2014
Shipping Line data (sample %)	55%	63%	64%	64%	64%	78%
TNPA Containers	Yes	Yes	Yes	Yes	Yes	Yes
TNPA Bulk	Summary	Detail	Detail	Detail	Detail	Detail
SARS data					Yes	Yes
TFR data		Yes	Yes	Yes	Yes	Yes
Trade industry bodies		Desktop research as required				
Economist reports		Desktop research as required				
Government departments		Desktop research as required				

Trade industry bodies, economist reports and government department datasets were desktop researched when required per commodity for the years where more information was needed. The shipping line data was not a complete set, thus the sample percentage is provided. Datasets for most of the Transnet operating divisions were available for earlier years as well, but not included in the analysis.

The next section of this chapter provides an overview of the shipping line dataset and what it contributes. This section also illustrates the depth of data by using graphics to describe certain angles taken on this dataset. A similar approach is taken in the subsequent section to describe the contribution of the TNPA container data, after which a further section briefly describes contributions made by other data sources.

Following the dataset discussions, an analysis was done on the shipping line dataset to determine model requirements that would be included in the model design later in this dissertation. Here different aspects are analysed that lead to the identification of parameters and values for these parameters. Some commodities are discussed in detail to explain the concepts and outcomes achieved, but not all can be provided. Some questions remain in certain areas where the data was unclear, led to dualistic answers or shortcomings were identified due to the 5-year limited time span of the data. These questions and shortcomings will be addressed in the next chapter through primary research methods.

5.2 Shipping line dataset

5.2.1 Dataset contributions by shipping lines

Shipping lines record a richness of data per container due to their planning requirements for container positioning and final loading per ship to ensure ship balance and stability in voyage. These container datasets include fields for:

- Commodity content (HS codes or other descriptive identifiers),
- Port of Loading (POL),
- Port of Discharge (POD),
- Weight per container (in metric tons),
- Type (reefer or normal),
- Size (20 or 40 foot),
- Number of containers (in TEU format).

This richness of data formed the primary resource in this study to provide a detailed understanding about the content of traded containers. The datasets used in this study included details of South African container ports from 2009 through 2014. A project team assisted with the processing and classification of over 340 000 lines of data into one combined dataset. The author played a pivotal role in the understanding, conceptualisation and application of the classification and analysis process.

The sample size obtained from shipping lines of the total full container volume as reported by TNPA improved from 55% in 2009 to 78% in 2014. The sample distribution is shown in Figure 5.1 for exports and in Figure 5.2 for imports. The detail received provided a higher percentage of exported container content than for imported container content. Despite this a small percentage of both imported and exported containers' contents remained unknown.

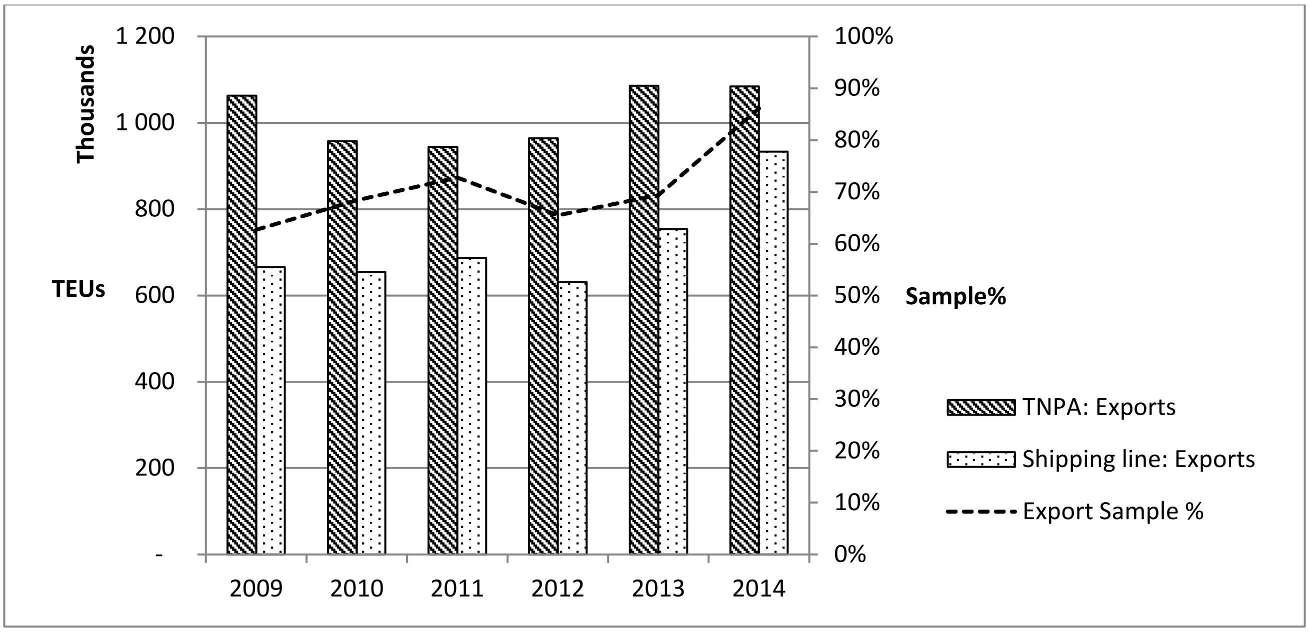

Figure 5.1: Shipping line TEU export data as percentage of TNPA volumes

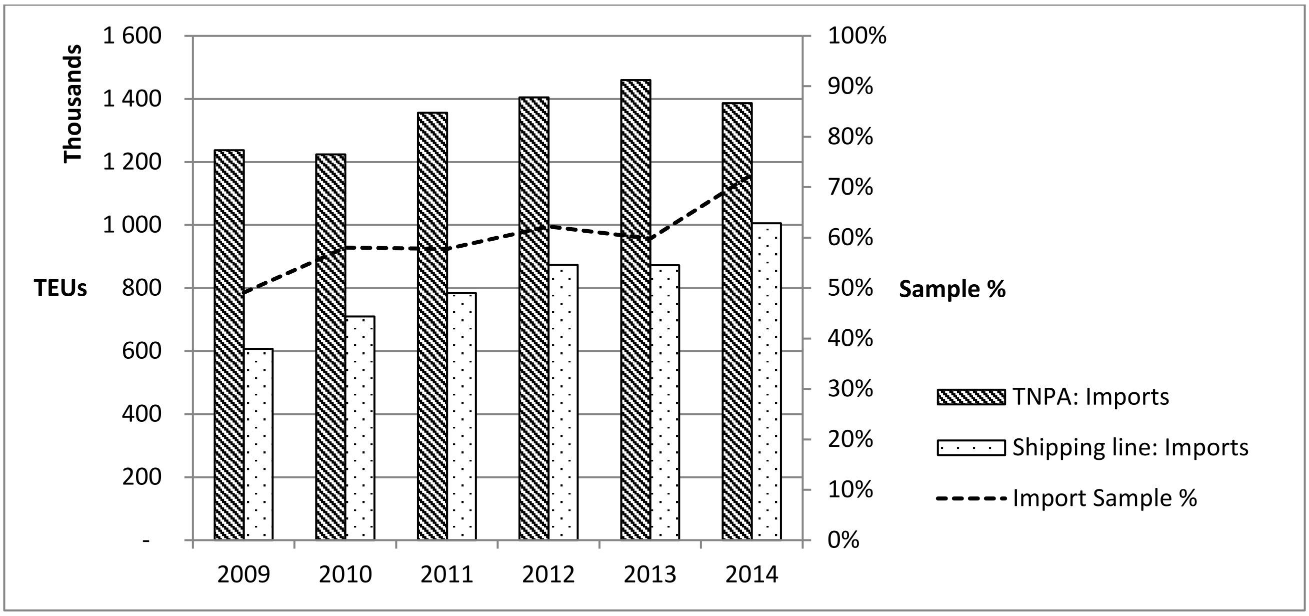

Figure 5.2: Shipping line TEU import data as percentage of TNPA volumes

These datasets include the most significant shipping lines frequenting the South African port network, namely MSC, Maersk, Safmarine, MOL and Ocean Africa. Over the years the number of shipping lines was increased from five to eight to increase the sample size and reduce the unknown part of the container detail. The extent of the detail received from shipping lines also increased in depth and detail over the sampling horizon. In other words, shipping lines in earlier years provided limited commodity detail, but the level of detail improved over time, enabling the research team to reanalyse data from earlier years and improving the sample accuracy. The shipping line commodity descriptions also became more detailed and more useful in the modelling process. None of the shipping lines distinguished in their data between the Port of Port Elizabeth and the Port of Ngqura. TNPA data does split these ports. To do comparisons and use the data it had to be combined for all analysis purposes related to shipping line data, and if not mentioned differently will be named as the Port of Port Elizabeth.

Datasets for 2015 and 2016 were also made available by most of the shipping lines, but due to project funding being stopped, these could not be analysed by the project team and are thus not included in this dataset.

5.2.2 Shipping line data example outputs

The detailed information received from shipping lines enables a vast number of different views and angles on the data. The purpose of this section is not to analyse the data to the fullest extent, but merely to elaborate on the richness within these datasets and the valuable inputs it introduced to the study. The next section reviews aspects from all the datasets one-by-one, with the purpose of identifying modelling parameters, base year values and forecast year values.

Figure 5.3 highlights Asia and Europe as South Africa’s major trading partners, as far as containerised commodities are concerned. In 2014 the shipping lines container sample showed 793 111 TEUs imported from Asia and 499 255 TEUs exported to Asia. Europe contributed 377 830 TEUs and 301 327 TEUs for imported and exported containers respectively. None of the other regions showed significant volumes compared to these two large trading regions, with the Middle East being the third-highest total of containers, contributing only 5.4% to the total. It would be beneficial in container forecasting to understand the country of origin and port of the imports and the destination country and port of exports. This detail is included with the shipping line sample data. So China contributes 51.3% of imported containers, Japan 11.5%, Thailand 9.4% and India 8.4%. Exported containers to China contribute 50.5%, India 19.1%, Pakistan 4.5% and Japan 3.8%. Imported containers from Europe have the following load countries: UK 26.1%; Netherlands 23.0%; Germany 10.4%; and Belgium 8.4%. Europe as destination countries for exports show Germany 26.1%, Belgium 13.2%, UK 10.4% and Italy 9.5%.

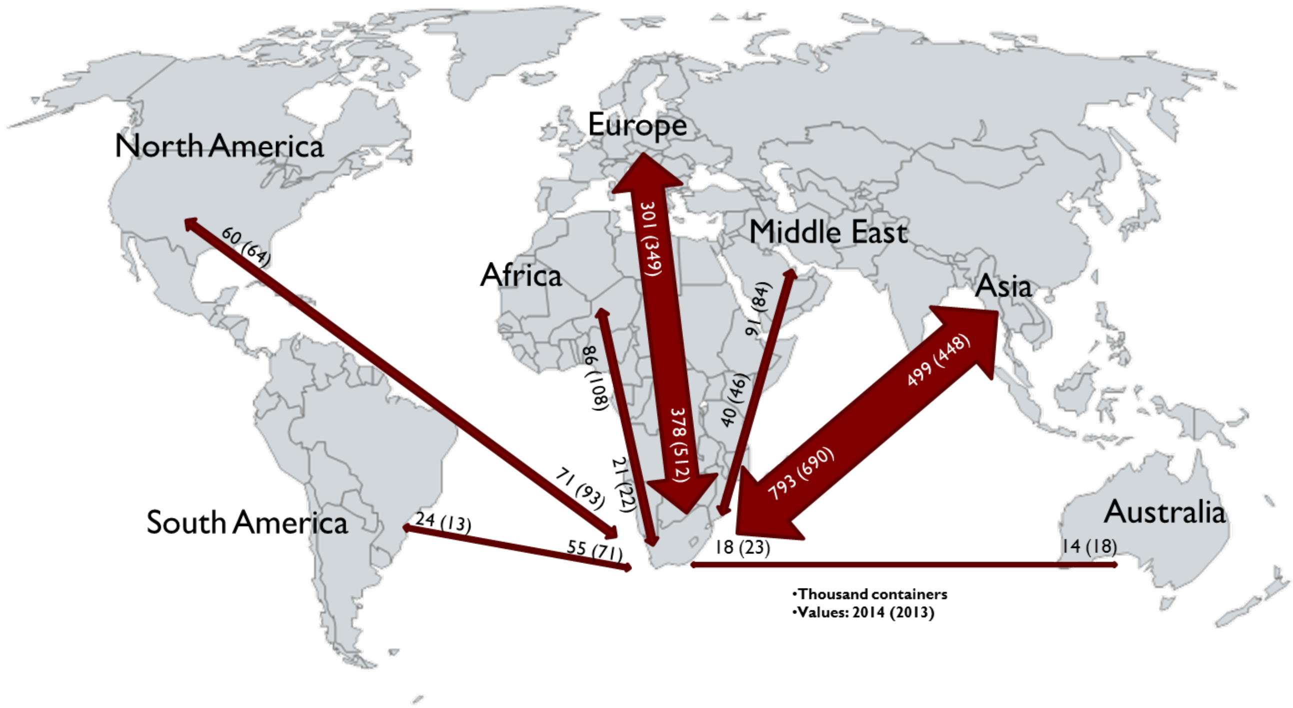

Figure 5.3: Regional trade flows from 2013 and 2014 shipping line container sample

Figure 5.4 shows the percentage change in both directions between South Africa and the different trading regions, with the arrows still indicating overall container volume. Although the trade volumes with Europe have historically been high, there is a serious decline in trade volumes to and from Europe, being displaced by major trading volume increases to and from Asia. In planning for long-term infrastructure, this trade change should be taken into account. Specific ports might be preferred for trade with these regions, and shifts in commodities traded with these dominant regions and/or specific countries could impact port infrastructure requirements.

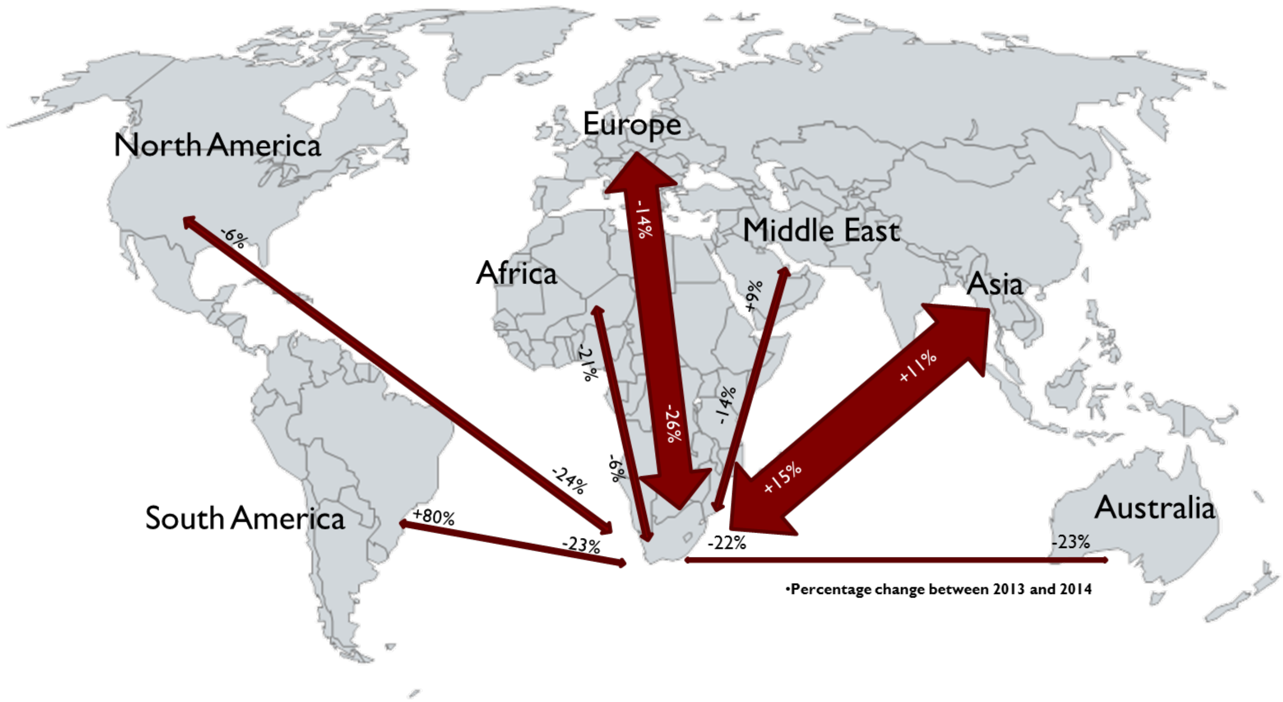

Figure 5.4: Regional trade flow change (2013 to 2014) from shipping line container sample (Arrow size indicates volume, not growth)

A large portion of the Port of Cape Town's container trade is with Europe, and this shift could potentially shift freight away from the Port of Cape Town to the Port of Durban. If the trend towards more trade with the East continues, this could place pressure on the Port of Durban container capacity.

Figure 5.5 shows how Asia has replaced Europe as the major volume recipient of traded export container volumes during the period of the container data sample. Export volumes to Asia showed an average growth of 9.5 % per annum, while Europe declined by 1.7% per annum over the same 5 years. From a low base, there was a notable sustained growth in exports to the Middle East of 10.6% per annum. The average annual growth of 37.8% from South America indicates that the BRICS alignment does seem to be of value for exporters with primarily chemicals and automotive components being exported in higher volumes to Brazil. Although this represents a high growth, it is from an extremely low base compared to Asia and Europe. If the trend continues long term, it could lead to a considerable change in volumes for especially the Ports of Cape Town and Ngqura, being on the preferred trading routes to South America. Container export volumes to Australia and Oceania have shown a steady decline of 11.3% average per annum. South Africa has limited shipping routes directly linked to this region, but trade is mostly via transhipment routes in the East. This makes these shipments costly and time-consuming and thus less competitive with other trade partners for this region.

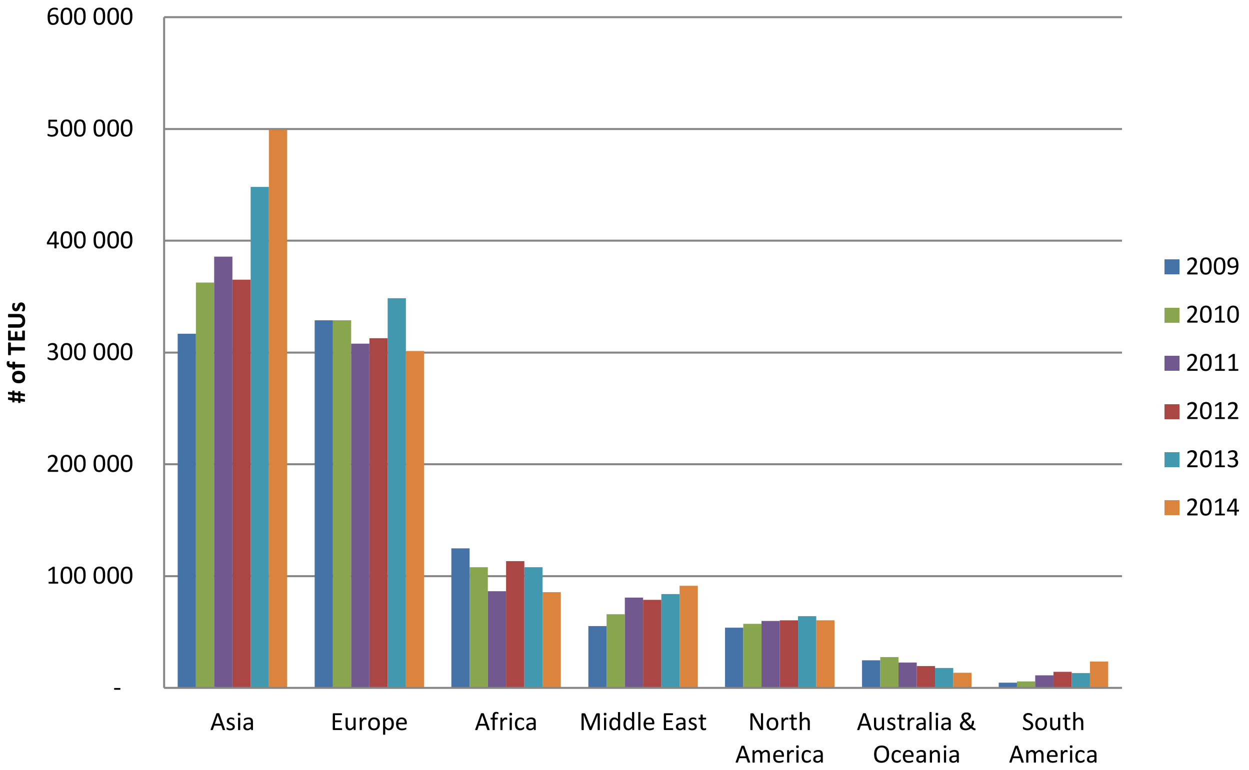

Figure 5.5: Regional export flow trends (# of TEUs 2009 to 2014)

Container exports to Africa seem to be volatile in nature, and declined overall by 7.3% average per annum. Road transport is, however, not included in these volumes and infrastructure upgrades with improved border control systems and challenges with port efficiencies could lead to this changing behaviour. Shipping to other African ports does happen, but in a limited capacity and with many challenges related to port efficiencies and delays. Port upgrades at sub-Saharan East and West coast countries could on the other hand lead to a surge in coastal shipments with a decline in road volumes. Road infrastructure into Africa is also in process of upgrade with large-scale investments and this could impact the behaviour of freight owners. The data indicates that it could potentially become easier to trade with more distant African countries via road networks, or it could indicate that the trade with other African countries is in decline. This is beyond the scope of this dissertation, but noteworthy to mention.

Figure 5.6 shows the changing trade relationships of container import volumes into South Africa. Asia showed an average growth of 7.0% per annum, while Europe declined by 3.1% per annum. A very large and significant shift can be seen especially from 2013 to 2014. Container import volumes from Australia and Oceania have shown a steady decline of 6.3% on average per annum. The other regions showed some changes in volumes, but no continuous significant patterns in any direction.

Over the period covered by the container data sample a significant shift in trading partners can be seen. This is the consequence of revised or new trade agreements and thus influenced by government activities and agendas. Any expected changes in future trade partnerships need to be taken into account with container infrastructure requirements. Commodity details included in these trade partner shifts need to be analysed with bulk shifts per commodity. These outputs need to be fed to the economists performing the FDM forecast to ensure that it is included in the forecast flow datasets used as input by the container model. From the container modelling framework perspective this should not be included as parameters, but the trends seen as high-level global influencers need to be identified and communicated to the economists.

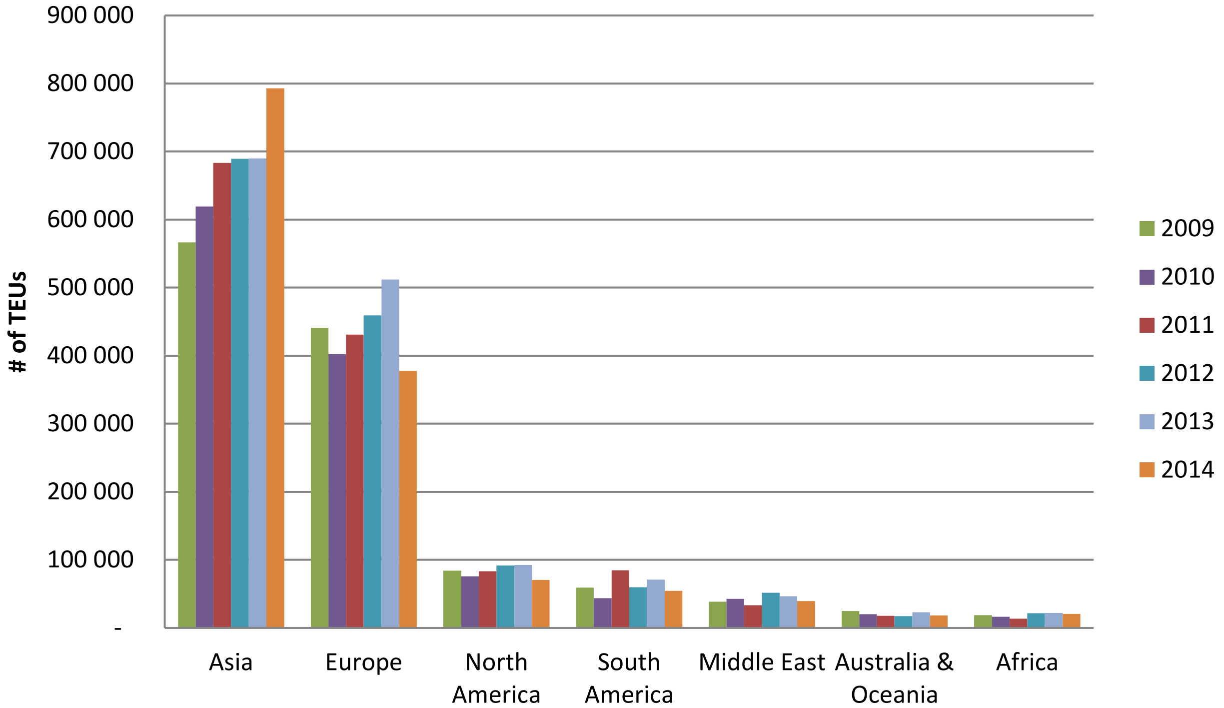

Figure 5.6: Regional import flow trends (# of TEUs 2009 to 2014)

Another view on the shipping line data is the content, i.e. commodities that are being traded. Many options to analyse this are possible. To indicate the available data, a view on the changes in specific commodity volumes can be analysed. Figure 5.7 highlights the 20 export commodities with the biggest volume changes for South Africa's largest trading partner, Asia.

A considerable decline in chrome (12 352 TEUs or 10.4% less), other mining (8 711 TEUs or 15.3% less) and paper (5 371 TEUs or 34% less) exports have been recorded. On the growth side, commodities that showed a significant increase in export volumes from 2013 were: Pulp of wood and paper (14 747 TEUs or 327% more); Citrus (12 494 TEUs or 90% more); Chemicals (9 911 TEUs or 93% more); Deciduous fruit (7 934 TEUs or 201% more); and Manganese exports (7 109 TEUs or 38% more). The 39 other commodities not specified showed a total increase of 19 726 TEUs or 48% indicating a reasonable growth across a number of commodity groups.

One aspect that raises concerns is the decrease in exports of finished paper and the increase in the export of raw materials for paper production, i.e. pulp. South Africa cannot afford to lose manufacturing jobs by exporting more raw materials and mining commodities and importing manufactured goods that it can and should produce locally. For the purpose and objectives of this dissertation, the government's long-term focus and impact achieved on enhancing manufacturing outputs, will have influence the types of commodities imported and exported and thus on the physical container types and container infrastructure requirements.

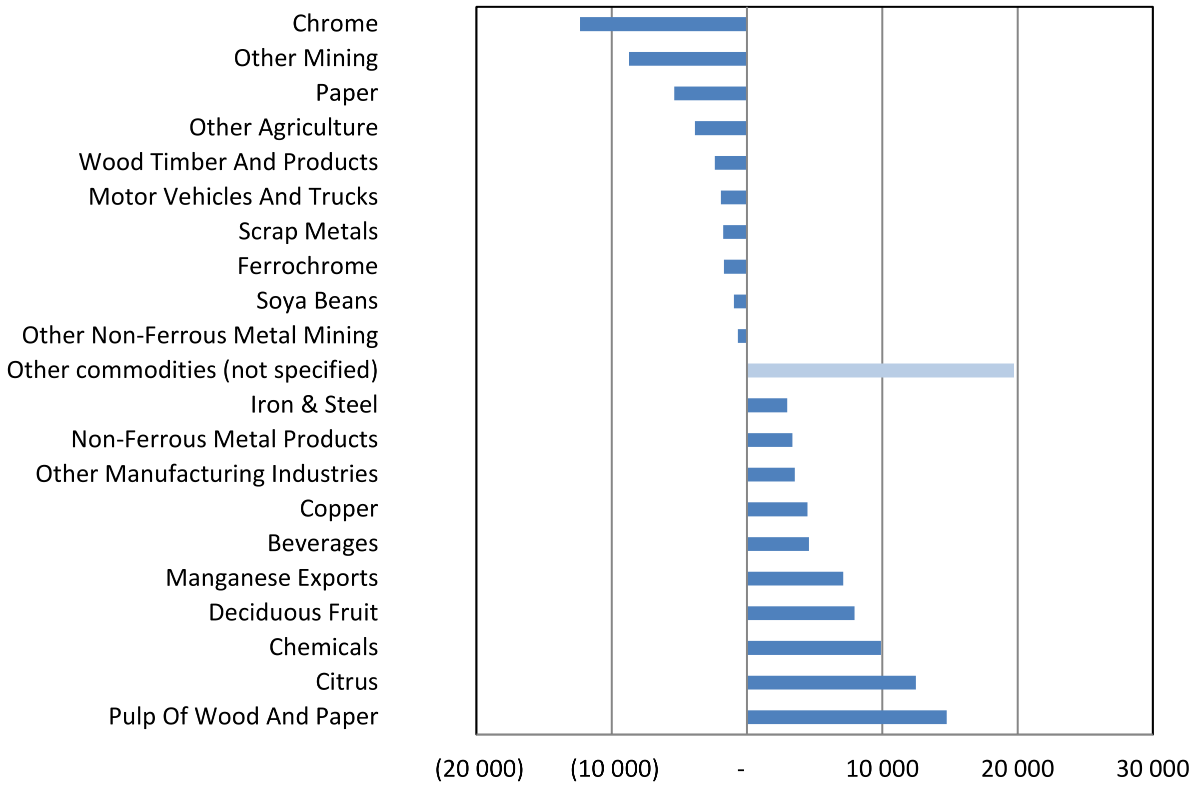

Figure 5.7: Asia export commodity changes (TEUs 2013 to 2014)

Figure 5.8 shows the **changes in imported container volumes from Asia**. Commodities that showed a significant increase in import volumes from 2013 were: textile products (31 060 TEUs or 31.4% more); metal products machinery and electronic equipment (23 775 TEUs or 26 % more); Chemicals (15 783 TEUs or 31% more); iron & steel (8 994 TEUs or 47% more); rice (7 974 TEUs or 74% more); and processed food (5 355 TEUs or 17% more). A decline in imported motor vehicles and trucks (3 766 TEUs or 7.5% less) and cement (1 723 TEUs or 43% less) have been recorded. The 37 other commodities not specified showed a total increase of 6 890 TEUs or 18%.These changes in commodity patterns with the trends they follow over the sample horizon were analysed per region, per country, and per South African port. Together with changes in bulk shipments and industry and economist data, it provides valuable data for inclusion in the forecasting model. For example, the increase in iron and steel of almost 9 000 TEUs equates to about 80 000 tonnes of iron and steel products that could easily have been done in bulk in the previous year. To really establish trends, the collective picture per commodity needs to be taken into account. This is done in the next section.

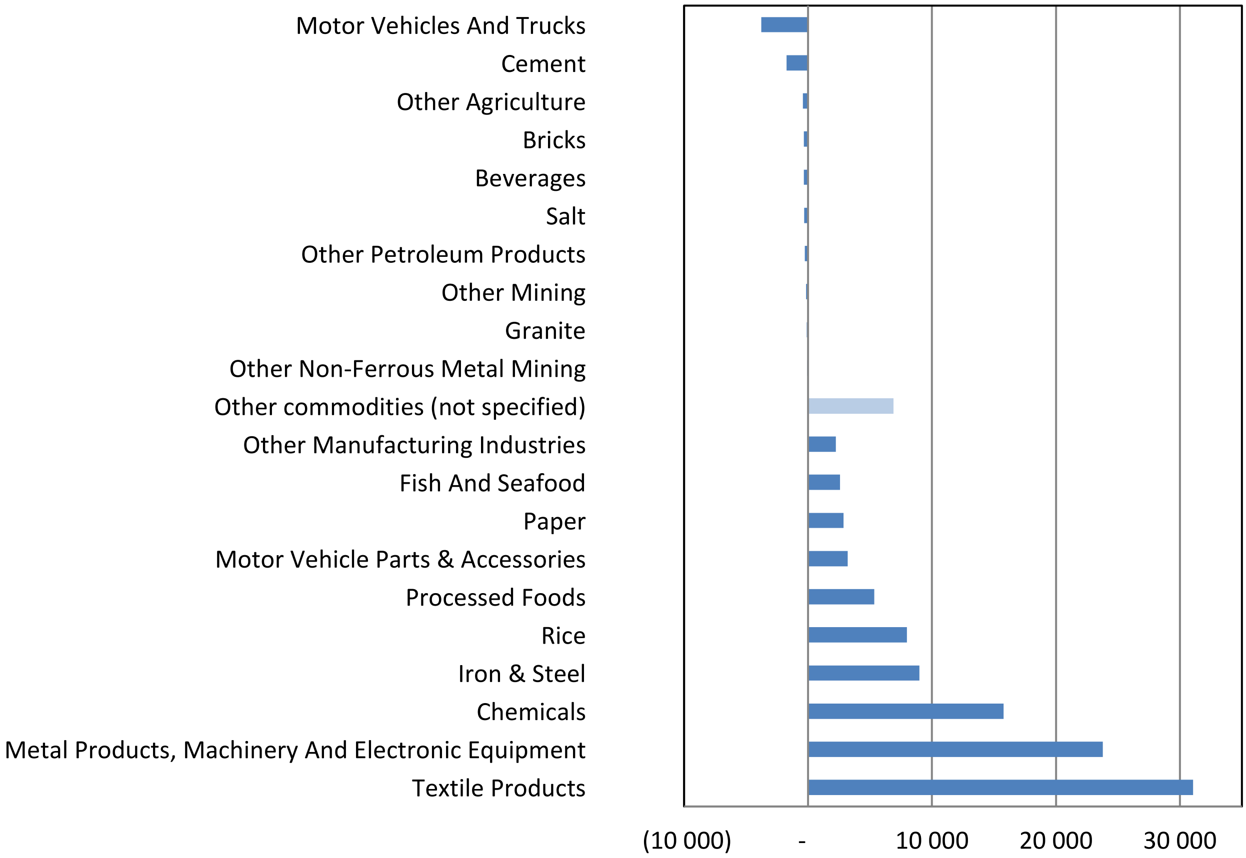

Figure 5.8: Asia import commodity changes (TEUs 2013 to 2014)

The shipping line data also provides a split between twenty and forty foot containers. These splits for exports and imports on a weight basis are shown in Figure 5.9 and Figure 5.10 respectively.

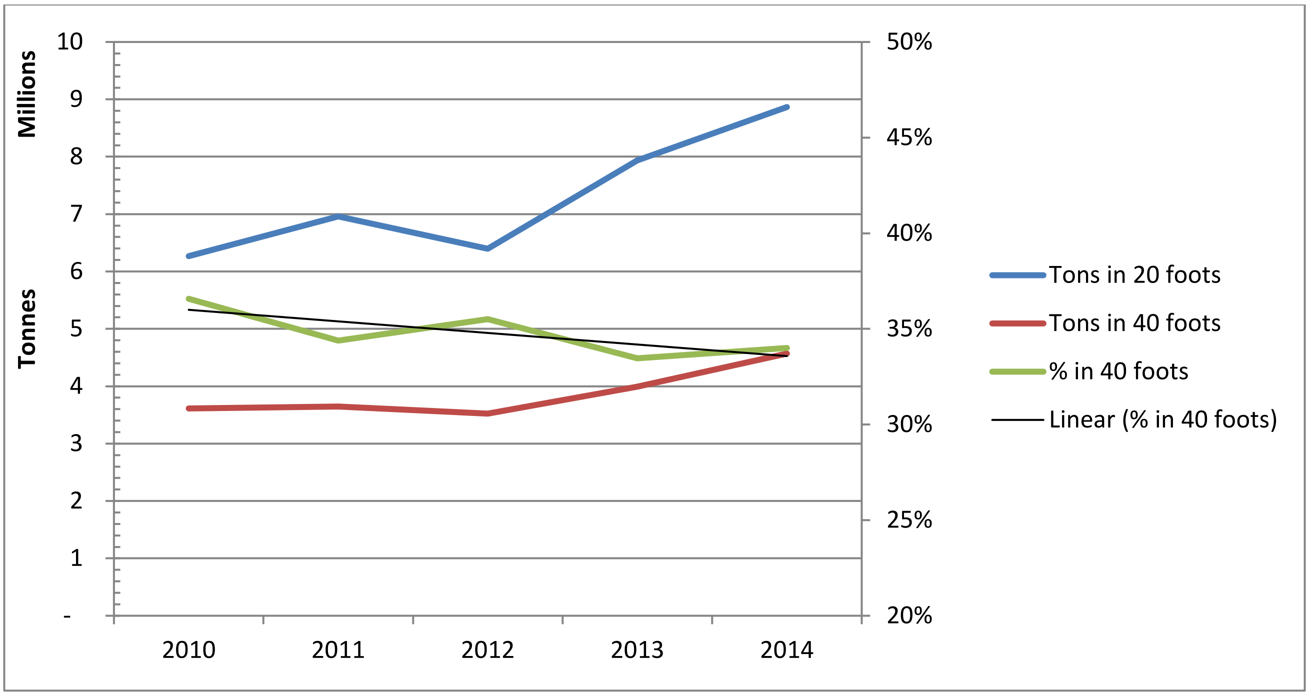

Figure 5.9: Export container tons – split between 20 foot and 40 foot containers

As mentioned in the literature review on international container sizes, forty foot containers are the more-preferred size at this stage. In South Africa forty foot containers make up around 35% of exported containers, but most of the recent weight growth went to twenty foot containers. For imported containers, forty foot containers make up about 45% of the present weight, and are increasing in preference.

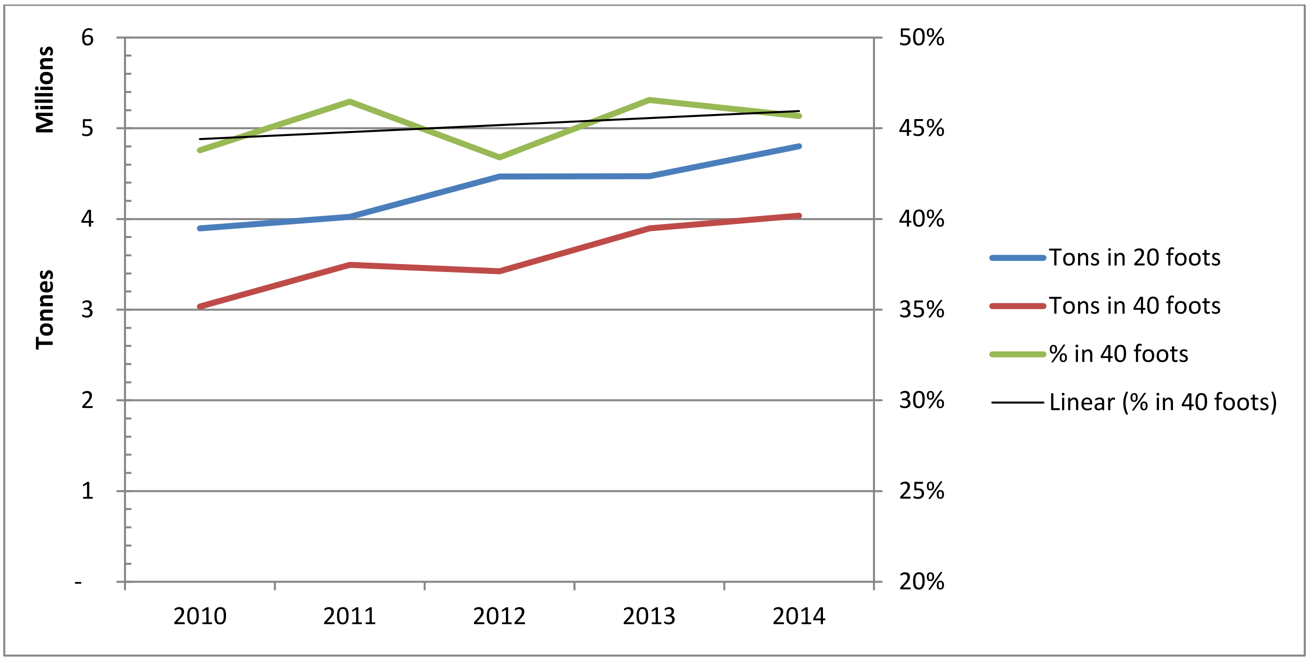

Figure 5.10: Import container tons – split between 20 foot and 40 foot containers

This interesting phenomenon seen with the trends can be explained once the size is analysed with the container content. It becomes clear that the heavier type of mining commodities exported by South African exporters leans more towards twenty foot containers being the more suitable size. Similarly lighter imported commodities, i.e. manufactured products, leans more towards favouring forty foot containers. This leads to a mismatch in supply and demand for container sizes and types, and a higher number of empty containers being exported and imported over the quay wall.

Figure 5.11 and Figure 5.12 provides the detail of the average weight per container for exports and imports respectively for South Africa and the three major container ports. A significant jump in container export weight can be seen for the Port of Port Elizabeth in 2013. After investigation it was found that this can be attributed to chrome, manganese, and other mining exports that effectively tripled in volume and their significant higher weight per container increased the average weight considerably. This effect could be due to a bulk terminal capacity constraint at the time. Port planners could know about this and then need a device or parameter in the container modelling framework to adjust for this once-off anomaly.

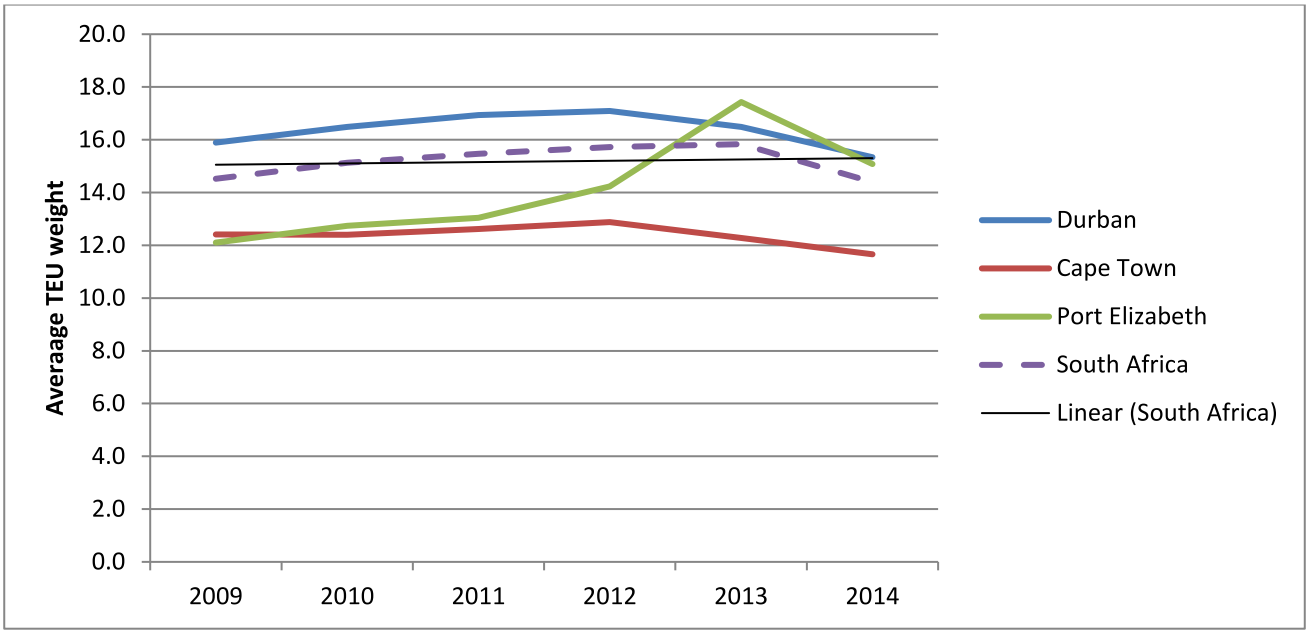

Figure 5.11: Average export container weight for South Africa and per major container port

Figure 5.12 shows a slight decline in imported container weight. The detailed commodities indicate that this can be ascribed to the changing nature and composition of imported products. Although denser packaging tends to increase the weight per container of specific commodities over time, the increase in high-technology manufactured items reduces the average weight of the total containers imported.

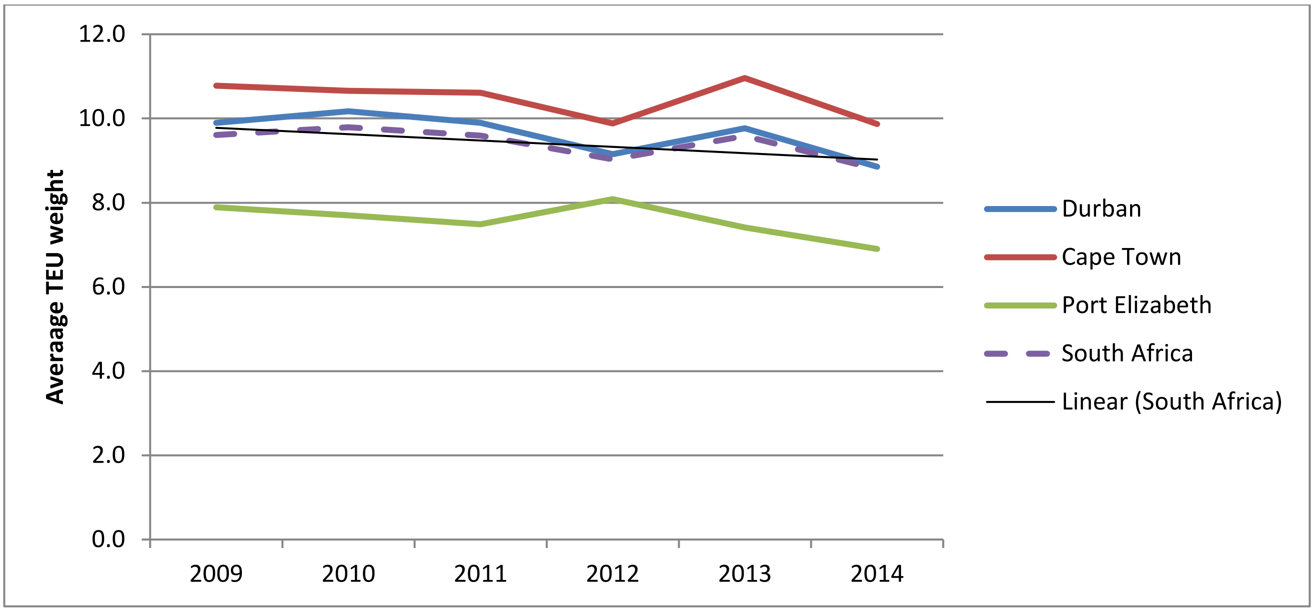

Figure 5.12: Average import container weight for South Africa and per major container port

The shipping line dataset provides a richness of data that needs to be analysed and could be used for numerous applications. For this dissertation’s focus on full quay wall containers, it is of utmost importance.

5.3 TNPA container data

TNPA provided **annual data** on the total container numbers handled by South African ports from 2002 to 2015. This includes container numbers shipped and landed per port in the following categories: deep-sea containers, transhipment containers and coastwise shipped containers. All three categories provide detail on both full and empty container numbers shipped and landed. It is important to highlight at this stage that TNPA do not capture details of the contents of containers on their information systems. Although each ship docking in South African ports needs to have detailed waybills for each container and its contents, this data is not captured by TNPA, but merely kept on file. This data is thus not available in electronic format and cannot be used to inform large-scale decision-making. Figure 5.13 indicates the export contribution per port for full containers.

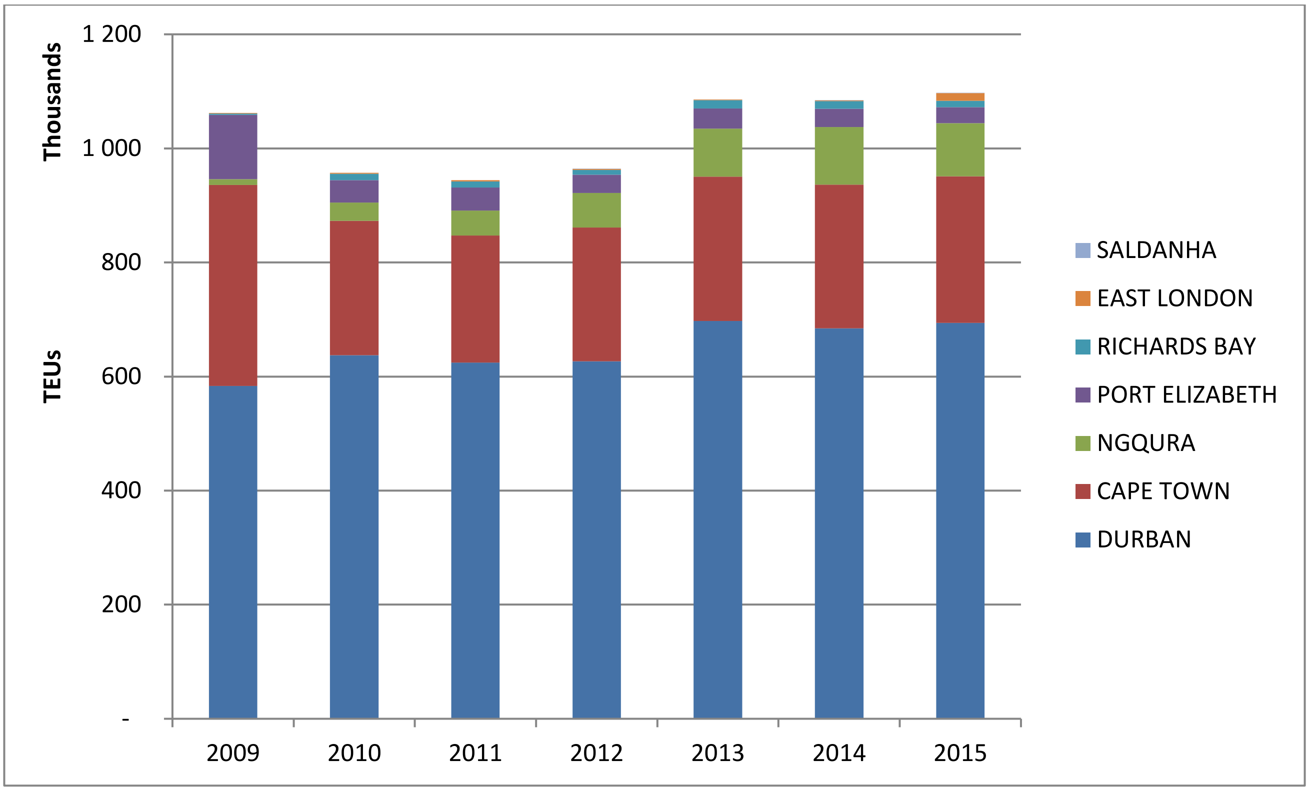

Figure 5.13: TNPA full export containers through SA ports

The Port of Durban was the major contributor in 2015 with 63% of export volumes followed by Cape Town with 23%. A significant shift can be seen with containers moving from Port Elizabeth to the Port of Ngqura, contributing 9% by 2015. Major shipping lines cannot afford to have their ships stop at both of these nearby ports, and more container ships prefer to stop at the Port of Ngqura.

Figure 5.14 shows the import contribution per port for full containers. The Port of Durban was again the major contributor in 2015 with 72% of import volumes and then Cape Town with 16%. Again the shift can be seen with containers moving from Port Elizabeth to the Port of Ngqura, contributing 8% of imported containers by 2015. The data from these could indicate a port preference, but it might also just be associated with shipping line route availability to the origin or final destination of freight shipped or received.

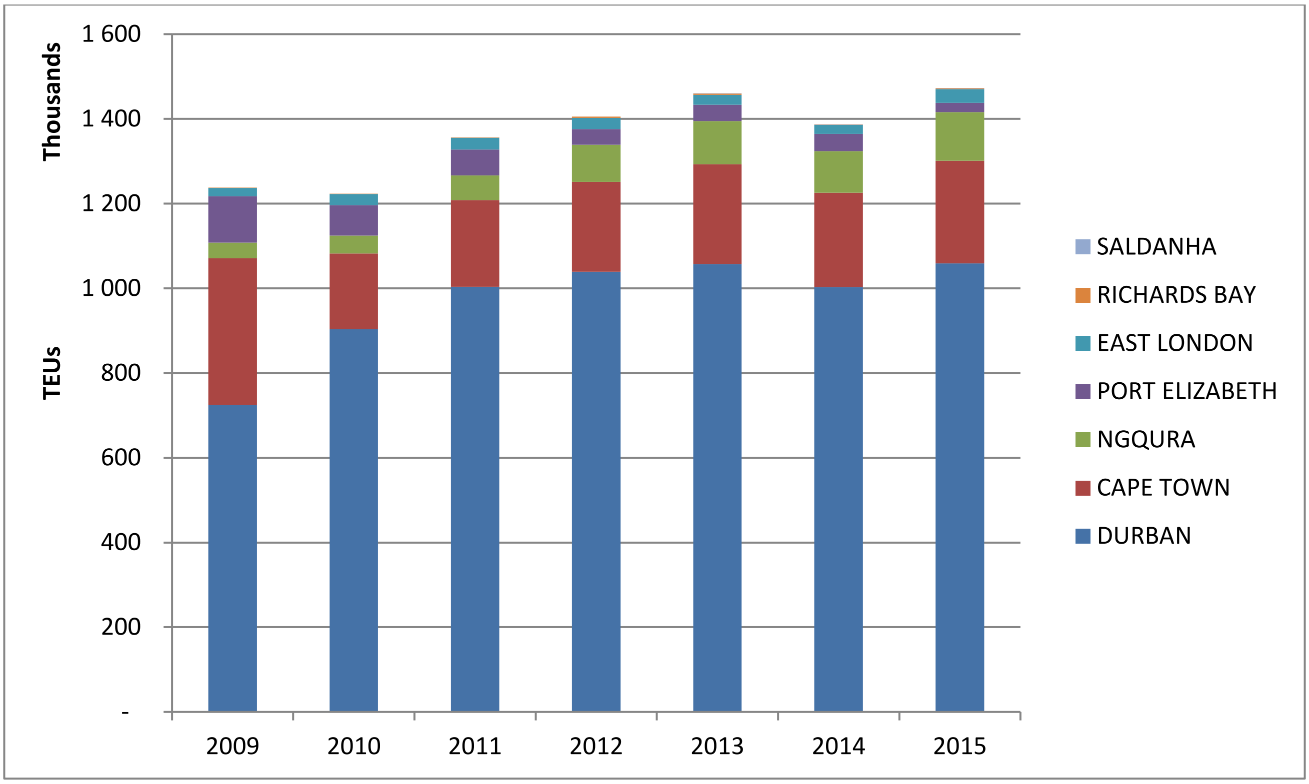

Figure 5.14: TNPA full import containers through SA ports

Some researchers often depict transhipped, coastwise shipped and empty containers as a percentage of the full containers per port to illustrate its significance in terms of the total port volumes. Figure 5.15 indicates the contribution for each of these elements as a percentage of full containers for the combined South African ports:

- Transhipped containers: contribute an additional 15–18%,
- Imported empty: contribute an additional 8–12%,
- Exported empty: contribute an additional 17–21% and
- Coastwise shipped: contribute an additional 1–1.5%

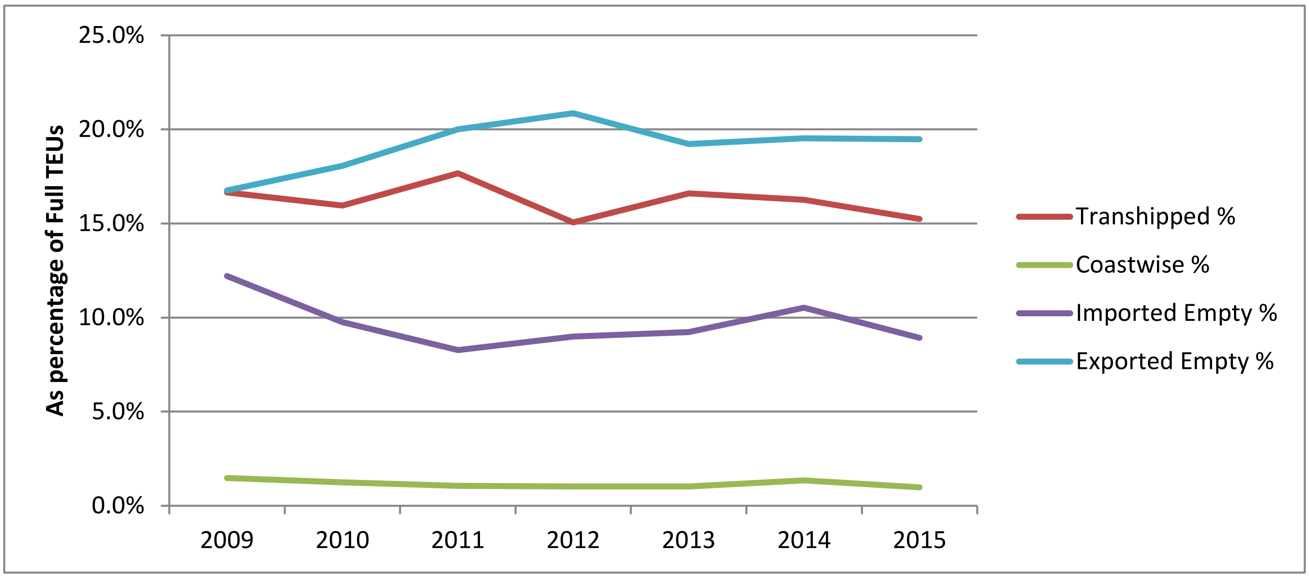

Figure 5.15: TNPA transhipped, coastwise and empty containers as percentages of full containers

The empty containers exported and imported show a significant discrepancy per port, as illustrated in Figure 5.16 and Figure 5.17 respectively for the Ports of Durban, Cape Town and Port Elizabeth and Ngqura combined.

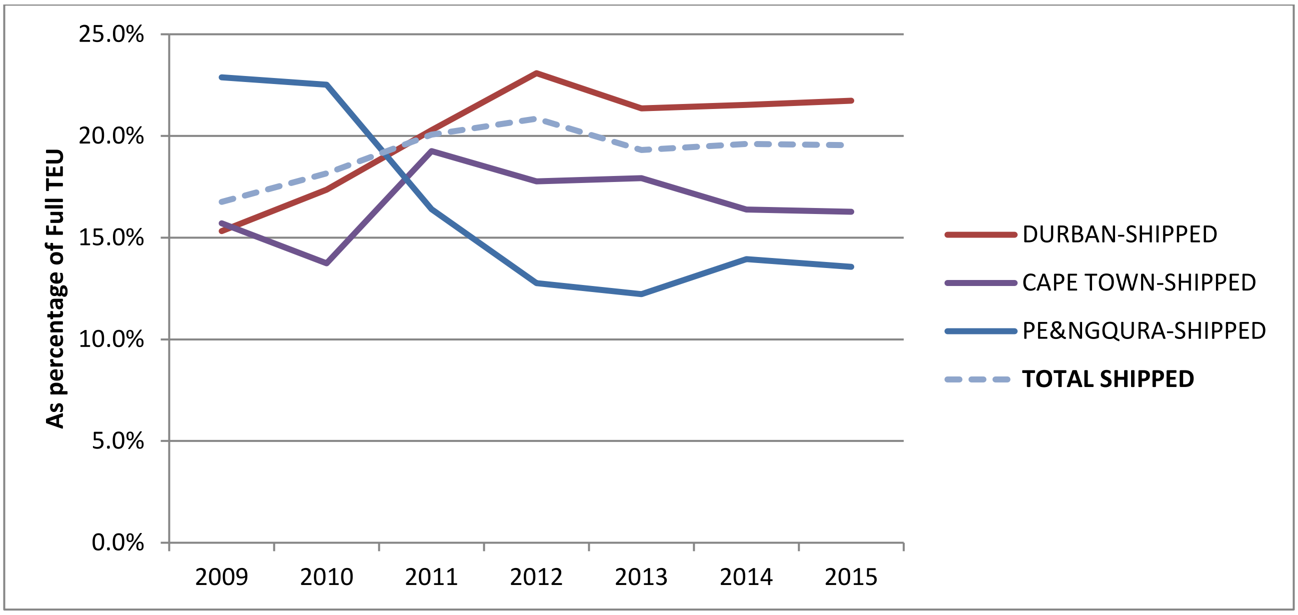

Figure 5.16: Shipped empty container percentages for significant container ports

Over the time period graphed, an average of over 19% of containers over the quay wall has been empty containers leaving the country. The Port of Durban has been a major contributor to the shipping of empty containers out of South Africa, with an average of over 20%. This could be attributed to the current import-export imbalance with trade partners in the Far East, with major shipping networks linking the Far East to the Port of Durban as preferred port. This imbalance is by volume and weight, and not by value. The effect of a negative trade balance was discussed in section 4.2.3, but this could have an impact only on the financing ability to import more, where here it is about the imbalance in volume and weight that creates a surplus of empty containers in South Africa that need to be returned to our largest import trading partners.

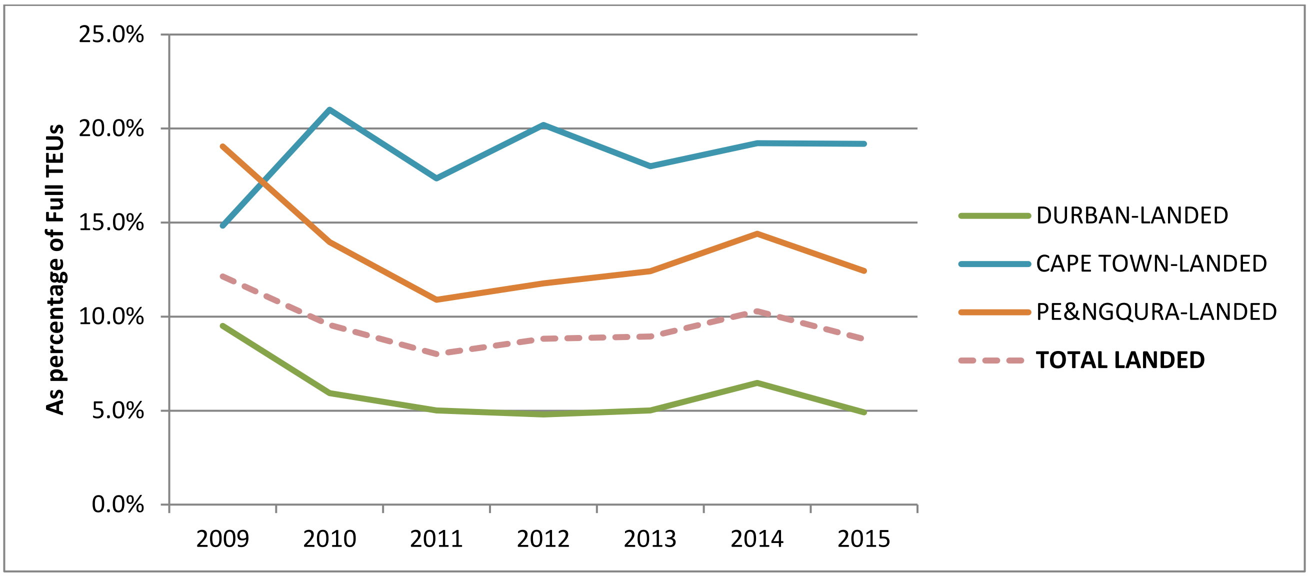

Figure 5.17: Landed empty container percentages per significant container ports

An average of below 10% of containers over the quay wall has been empty containers entering the country. Cape Town has been a major contributor to the receiving of empty containers. This could be attributed to the current import-export imbalance of refrigerated products, mostly fruit being exported, through this port. The Port of Durban's import-export imbalance also explains the inverse for the landed empty containers showing the Port of Durban being below the average.

Many aspects influence the empty container scenarios above. These aspects need to be understood for planning accuracy. Some of the trends might be explained by the different container types required, or seasonality of the demand for empty containers. An example of this is empty reefer containers required for fruit exports in season with very limited import of refrigerated commodities at the same port at the same time of year.

The container datasets from TNPA do not provide any view on the contents of containers, container types nor on the origin or destination of the containers. Thus no abstractions can be made from this data to identify: freight owners; trade partners; commodities; or container types. It does provide the number of containers, empty and full, that cross the quay wall and this figure can be used for modelling purposes. Current available data from TNPA, shipping lines or any other source do not provide any insight into the level of detail defined in section 2.1.1. It was therefore decided to group the physical types into six physical-type families to provide for a lower modelling complexity than trying to be specific for all 83 commodities over all the forecast years. More detail on this in section 6.3.4 and Appendix F.

Port planners can use these numbers as a predictive index for future transhipped, coastwise and empty container movements together with information about specific port strategic plans to, for example, target transhipment cargo. It is easy to do historical analysis like this and then forecast for each of these typologies by whatever forecasting technique is found to be most applicable to each dataset. More detailed parameters and higher accuracy would, however, be better for long-term forecasts. These aspects are borderline elements that the researcher would prefer to exclude from this study, but due to its importance for port quayside infrastructure planning, it cannot be completely ignored.

5.4 Other contributing datasets for commodity volume validation

5.4.1 Linking industry and commodity datasets to national port level outputs

The aim here is not to do a complete analysis of the extent of the TNPA, SARS, TFR and shipping line datasets, but merely to illustrate the contributions from these datasets to paint a complete picture. Several single-dimension analyses can be shown on individual views on commodity content, loading port/country/continent, destination port/country/continent, weight per container, container types and sizes. Some trends can be shown on two or three combinations of these aspects, but that would be too extensive for the purpose here. Section 5.4.6 will illustrate the model design requirements identified from a complete and detailed analysis of the various other datasets in combination. This section will merely illustrate how these non-core datasets contributed to understand the complete container content picture.

But first, it is important to explain how the sample shipping line data in combination with the other datasets have been used to estimate the unknown shipping line container content. Figure 5.18 explains the logic and method used to estimate the unknown container content. For most commodity groups an accurate traded volume in tonnes per year can be desktop researched from a combination of sources, i.e. related industry, SARS, TFR and/or Government Department datasets. In most cases these tonnes are available per port and in some instances per destination country. These traded quay wall tonnes will be split into container tonnes and bulk tonnes. The latter is reported on by TNPA, providing bulk tonnes per port that crossed the quay wall. If the bulk tonnes are subtracted from the total tonnes, the total container tonnes can be calculated. If the known container sample tonnes are subtracted the remaining unknown container tonnes can be calculated. In the modelling process, the total container tonnes per port are called the 'inflated' container tonnes. If the weight per container per commodity is used to calculate the total container numbers per port over all commodities, this number should match the total full container numbers recorded by TNPA per port. Thus, even though TNPA report commodity and content blind on the total full containers per port, it does assist to estimate the remainder of the container sample. In principle this sounds very easy and straightforward to do, but it can sometimes be difficult to match up all these numbers per port and per commodity.

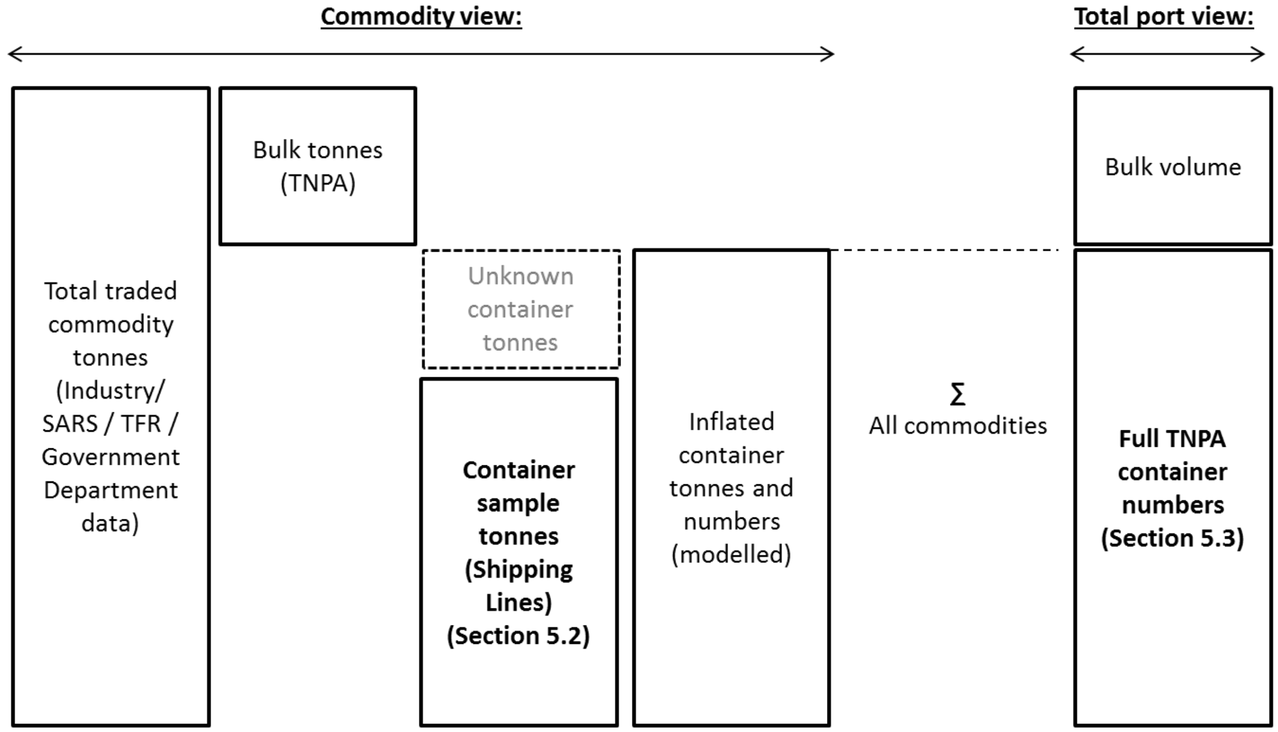

Figure 5.18: Logic used to establish the unknown container tonnes per commodity

5.4.2 Trade industry bodies and economist reports

A balancing factor in all the data analysis was historic volumes from industry reports and websites. Teams of economists from agriculture, mining and manufacturing industries provide reports and publish details on total volumes produced, imported and exported for various calendar years or seasons in their annual reports. For example, Grain South Africa (2017) stated that in 2014 South Africa exported 2.1 million tons of maize, 26% of which went to Taiwan, and 14% to Zimbabwe. From these numbers origin, destination and preferred ports can be deduced. This data can be used to complete the sample for specific commodities and to verify the remaining portion of commodity exports and imports not seen in the container sample or in the TNPA bulk export volumes.

Various trade industry/government bodies exist that support the freight owners for that industry on a port/industry/destination level. The list of these entities is too extensive to mention in this dissertation. As an example a few of these entities are:

- The Perishable Products Export Control Board (PPECB) that annually reports on total perishable produce exported in containers through the South African port network.
- Department of Minerals report on the tons of various minerals mined and extracted.

- NAAMSA reports on the number of vehicles sold, imported, exported and produced locally.
- Various agricultural boards, such as the South Africa Sugar Association and Grain South Africa, report on their sphere of influence or responsibility.

These industry body volumes can be used as a cross reference and validation for the volumes obtained from TNPA, TFR, shipping lines, and SARS data. Although the extent of reporting on all of these industry bodies' data is beyond the scope of this dissertation, it provides an invaluable input where other data does not confirm the exact volumes or if some aspects are questioned. These reports often refer to ports used and/or specific volumes, or destination countries and volumes exported per season, or other valuable information that can be useful in providing missing pieces to complete the understanding of the current puzzle in order to build the forecasting model. A team of desktop researchers is employed every year to assist and build on the data obtained from these sources.

Similar to the economists reporting on historic freight volumes for import and export, they also provide forecasts that could range between short- and long-term depending on the industry. Some of these of economists provide various scenarios for low-, medium- and high-growth scenarios that have proved valuable in transport modelling validation.

5.4.3 TNPA bulk data

The TNPA bulk dataset provides the following details: port, direction of shipment, billing date for ship, commodity classification, cargo type classification and shipment weight in tonnes. The direction of shipment indicates import or export, but also distinguishes between deep-sea shipments and coastwise transfers nationally and internationally. The commodity classification is a unique set of historically most important commodities traded in bulk over the quay wall. This classification often combines primary and processed products, e.g. wheat and products thereof. This is problematic, since these two products should, under an SIC classification, be in separate categories for agricultural produce and manufactured products. The cargo type classification distinguishes between bulk, break-bulk, liquid, and vehicle shipments that provide insights into potential container types these bulk shipments might merge into in future, if possible at all. The data were made available for 2010 to 2015. The volumes provided will be for the 2015 calendar year, if not stated differently.

The number of different views that can be taken on the TNPA bulk data are numerous, considering the dimensions being various ports, commodities and direction of shipment (import vs export). A number of different graphs and explanations would need to be included to provide some background to the South African port context to highlight potential future container traffic growth. Important at this stage is to consider the terms of palletisable and containerisable freight that were introduced in section 2.3. The bulk data analysed provided insight into which commodities are not completely containerised yet, thus leaving room for future container growth above trade growth. It also provides the balancing factor to ensure that each commodity is understood in full as described in section 5.4.1.

TNPA bulk export and import volumes per port are shown in Figure 5.19 and Figure 5.20 respectively. The export/import balance by volume is extensive with 77% of quay wall bulk volumes being exports (179 million tons in 2015) and 23% being imports (55 million tonnes in 2015). Richards Bay and Saldanha contribute by far the biggest export volumes due to the coal (78 million tonnes) and iron ore (61 million tonnes) export terminals situated at these ports respectively. Other commodities contributing to the Port of Richards Bay's export dominance are magnetite (4.4 million tonnes), chrome (4.2 million tonnes), ferrochrome (2.5 million tonnes), wood chips (1.8 million tonnes) and chemicals (1 million tonnes). Other commodities contributing to the Port of Saldanha's total volume are manganese (1.9 million tonnes), and iron and steel (0.75 million tonnes).

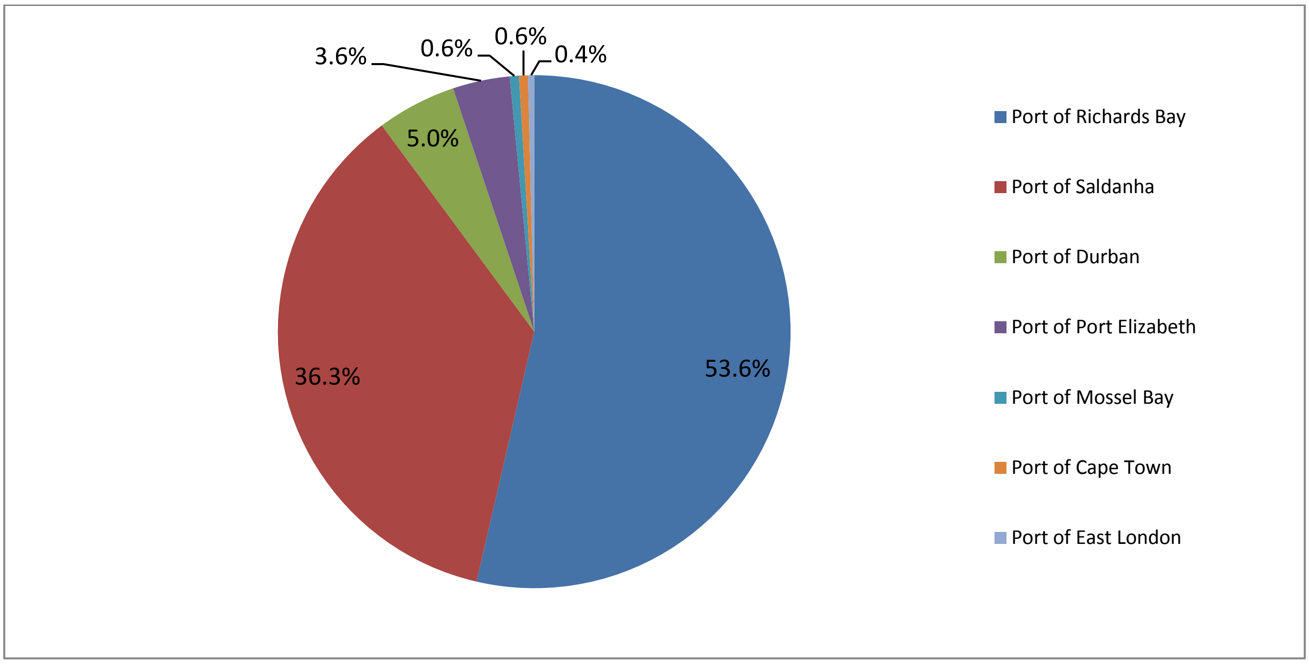

Figure 5.19: Bulk export volumes per port for 2015

The Port of Durban is the third-biggest bulk export port with major commodities being manganese (2.3 million tonnes), motor vehicles (1.7 million tonnes) and petroleum products (1 million tonnes).The Port of Port Elizabeth is the fourth-biggest bulk export port with major commodities being manganese (5.9 million tonnes) and motor vehicles (0.6 million tonnes).

On the import front, the Port of Durban contributes the highest bulk import volumes due to the crude oil (16.6 million tonnes) and fuel (5.8 million tonnes) imports at this port, showing South Africa's dependence on energy imports despite the rich coal deposits available. Other dominant imported commodities at the Port of Durban are vehicles (2.6 million tonnes), wheat (1.6 million tonnes), processed foods (1 million tonnes) and chemicals (1 million tonnes).

Saldanha and Richards Bay also contribute significant import volumes. The Port of Saldanha is dominated by crude oil imports (6.6 million tonnes). The Port of Richards Bay is dominated by imports of coal (1.8 million tonnes) and alumina (1.3 million tonnes). The Port of Cape Town is the fourth biggest bulk import port with the only dominant contributing commodity being fuel (1.8 million tonnes).

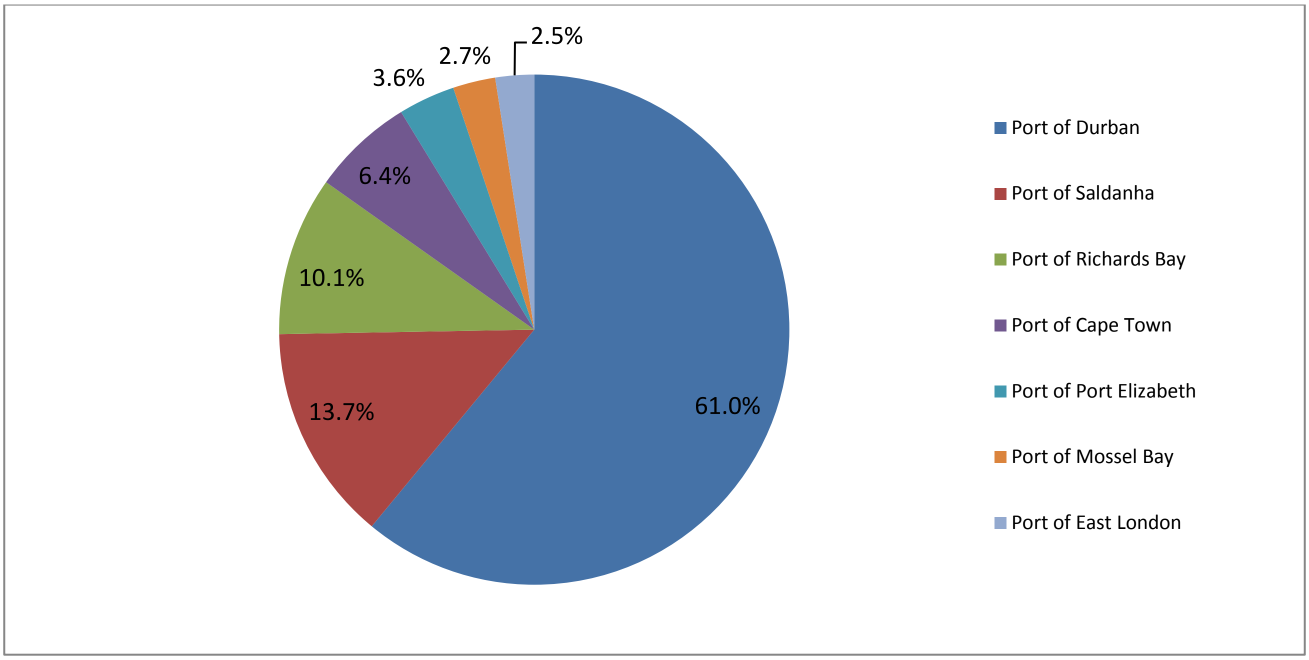

Figure 5.20: Bulk import volumes per port for 2015

All of these volumes point towards South Africa's dominant commoditised mining economy. Many of these mentioned high-volume commodity groupings would probably never be suitable for container transport in such large volumes, but some smaller volumes to specific destinations could be transported in containers. This needs to be investigated, but the detail for this is not available from TNPA datasets. If South Africa would in the future change from this commodity-based economy to producing more manufactured outputs, the bulk volumes could decrease and/or be replaced by more containerised manufactured commodities.

TNPA bulk export and import commodity volumes for all ports collectively are shown in Figure 5.21 and Figure 5.22 respectively for only the top ten commodities by volume. In these graphs the TNPA commodity descriptions are used.

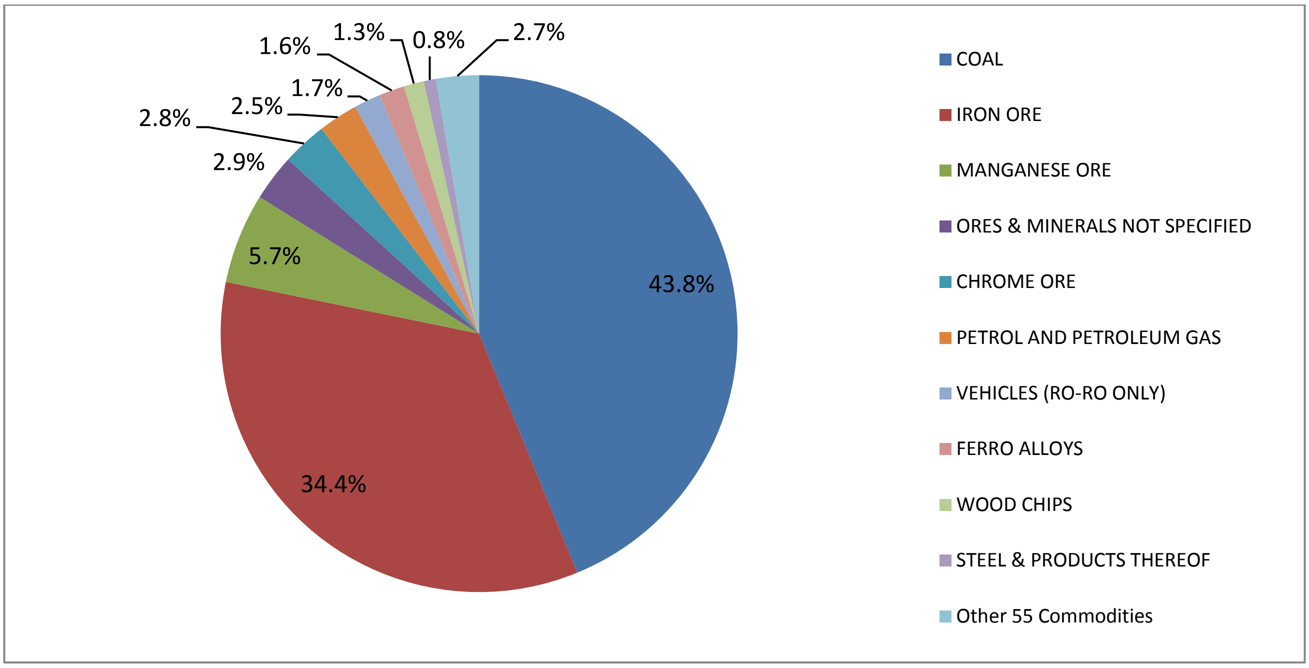

Figure 5.21: Top ten TNPA bulk export commodities in 2015, all ports

Some of these commodities have already been mentioned in the port breakdown discussed above, and only specific highlights will be repeated. South Africa exports primarily mining commodities in bulk in a low-processed format, with 84% of the volume made up of coal, iron ore and manganese. The highest volume of manufactured items in bulk export is vehicles contributing 3 million tonnes to exports, primarily with roll-on roll-off (RORO) ships used for these shipments. Very little containerisation is expected for these bulk commodities, with possible exceptions being vehicles, wood chips, and steel and products thereof. Some destinations, routes or subgroups of these commodities might be suitable for some level of containerisation in the future.

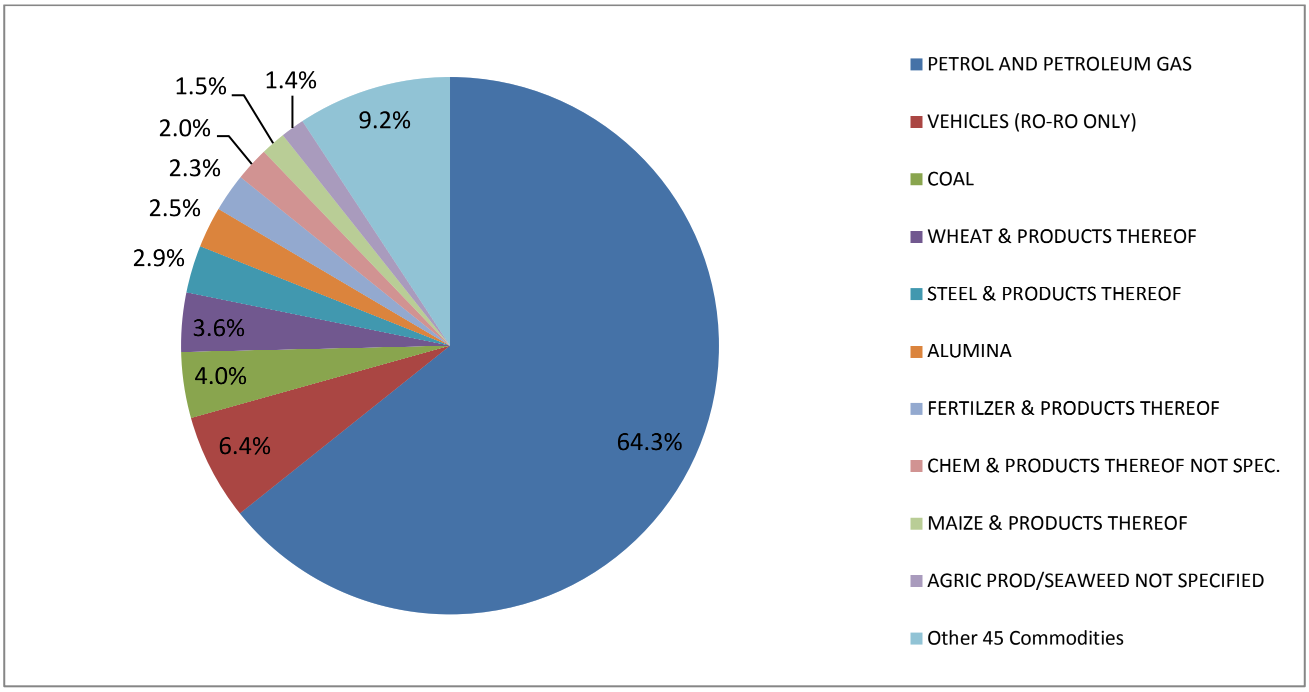

Figure 5.22: Top ten TNPA bulk import commodities in 2015, all ports

Bulk imports reported by TNPA are heavily skewed towards variants of fuel and gas, contributing 64% of total bulk quay wall volumes, a total of 35.3 million tonnes. This includes crude oil and natural gas, but also refined variants like petrol, diesel and aviation fuel. Other notable contributions are from vehicles (3.5 million tonnes), coal (2.2 million tonnes) and several mining and agriculture-related commodities in various phases of processing. For the preferred bulk import commodities some might also be targeted due to volumes, origin of transport, or the shipping routes followed. Commodities to be considered for future containerisation might be maize and wheat products, steel and steel products, chemical and fertiliser products and finally the agricultural products mentioned.

TNPA uses a list of 96 codes for reporting purposes, that is a combination of processed and non-processed products, i.e. maize and products thereof as shown in Figure 5.22. This effectively combines the agricultural and manufacturing sector by mixing agricultural maize production with processed food production outputs. This adds a level of complexity that is difficult to work with in modelling and forecasting for individual commodities from an economic input-output model perspective. On request a more detailed level of commodities was made available where these higher-level reporting combinations could be split into their respective sub-elements.

These port volume graphs are so dominated by coal, iron ore and manganese exports and crude oil and fuel imports, that it would be better to exclude them for analysis purposes. These high-volume bulk commodities will be transported by dry bulk and liquid bulk ships, which are not suitable for container transport, and thus outside the scope of this dissertation. Despite this, considerable quantities of these commodities were found in the shipping line datasets. This might be due to capacity issues at bulk terminals, and if these issues are resolved it might free up container terminal capacity again. Figure 5.23 and Figure 5.24 provide a commodity view for exports and imports respectively for all ports excluding these high-volume bulk commodities.

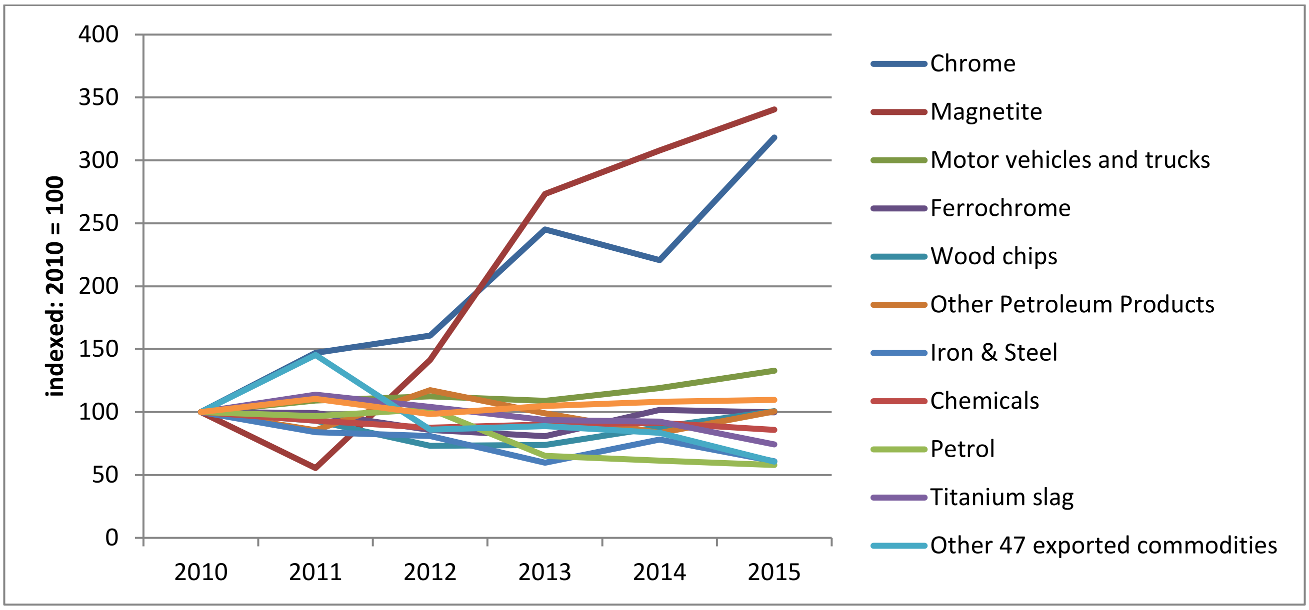

Figure 5.23: TNPA bulk – Indexed trends for top ten export commodities (Excl. coal, iron and manganese)

These values have been indexed on 2010 volumes to indicate the growth or decline in volumes for these commodities. Some of the declining commodities have been moved into containers and away from bulk shipments. Chrome (26% per annum) and Magnetite (28% per annum) have contributed significantly to the export growth experienced by various ports over the time period. This is linked to continuous favourable commodity price changes in these specific mining commodities. This led to a bulk export growth of 1.9% per annum over the period. If the growth of chrome and magnetite were to be excluded, the remaining commodities would decline by 4.0% per annum. Major decline of around 10% per annum has been experienced by petrol, iron and steel and the other non-top-ten commodities collectively. Closer investigation into the declining commodities is required to determine whether they are in the process of shifting to containerisation completely, partially or are declining in trade volumes. If high growth or decline is not due to the containerisation effect, aspects the desktop researchers need to identify are industry disruptions caused by new mines or refineries opening, or the closing of depleted mining facilities and associated factories. This will be discussed in detail during the next section of this chapter.

Imported bulk commodities increased in volume by 2.8% per annum. Some commodities like iron and steel showed a 10% increase per annum, indicating an industry shift from manufacturing locally and exporting to importing iron and steel products. This might explain the challenges the steel industry has experienced in the last couple of years, unless a shift towards containerisation in one or both directions has taken place. Other commodities from the non-top-ten commodities group that increased over the time period was a mixture of agricultural and mining commodities, i.e. maize, soya beans, cement, titanium ore, salt and gypsum.

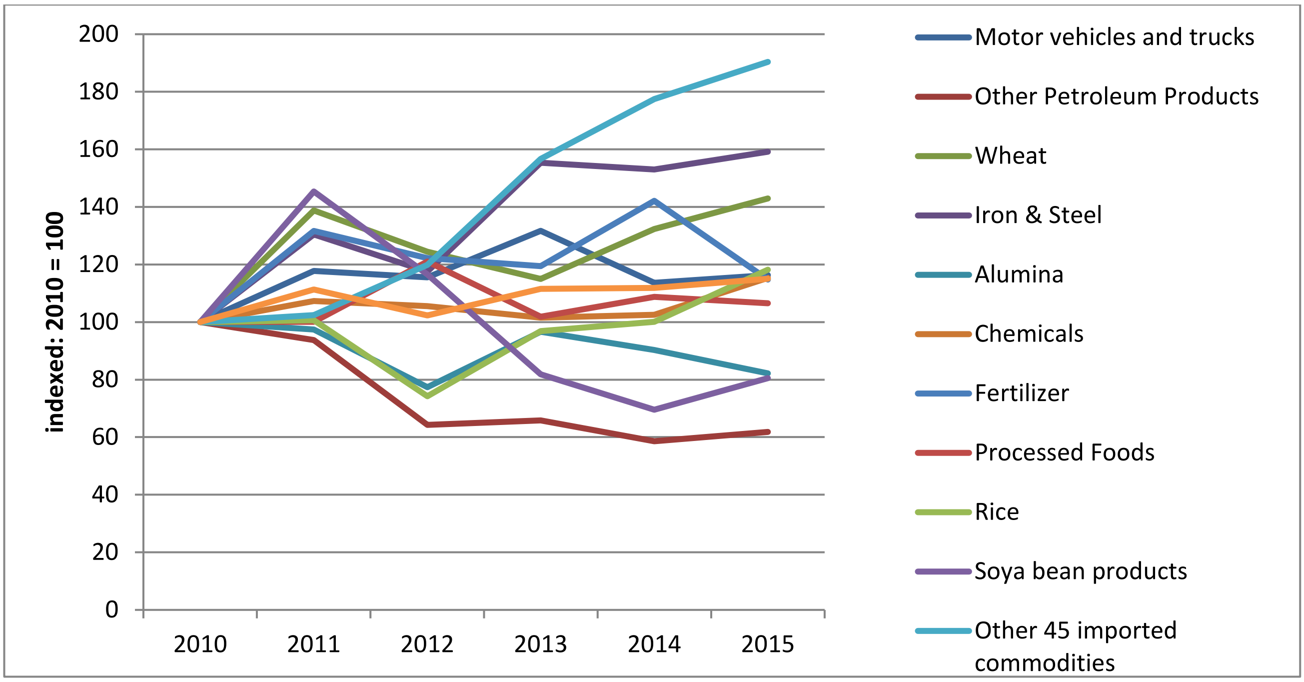

Figure 5.24: TNPA bulk – Indexed trends for top-ten import commodities (Excl. crude, fuel and coal)

The major contribution from the TNPA bulk freight import and export volumes was highlighting commodities that have not yet been containerised. The question that remains is how much of these commodities would freight owners prefer to ship containerised in the future vs being traded in bulk. The desktop research also focused on finding times of bulk terminal capacity constraints that caused unnatural containerisation effects. Some of these answers can be found by analysing the bulk commodity volume trends over time. I.e. a decrease in bulk volumes might indicate a decline in trade volumes, or a shift towards containerisation as the preferred method of shipment. The next question would then be whether this will continue, and whether it will continue being 100% containerised or whether a containerisation ceiling below 100% would be reached. Some commodity groups are a combination of a number of different sub-commodities, and some of these might be containerised while others would not be. The container forecasting modelling approach should make provision for all these aspects by means of parameters and values for these parameters need to be determined.

5.4.4 SARS data

SARS captures detail data on trade data across borders and via ports. This data is based on customs declarations from freight owners, at a very detailed level and provides the following aspects:

- Border posts or port of trade used;
- Country of origin, export and destination;
- Tariff codes that can be linked to HS codes;
- Export transport method, being air, road, rail or maritime;
- Weight of the traded goods;
- Customs value.

The detailed data for 2013 and 2014 was made available through Transnet to the researcher. Most of these fields are self-explanatory; however it is important to highlight that this data includes freight shipped from landlocked countries (i.e. Botswana, Zimbabwe, etc.) across South Africa. For example, copper from Zambia (origin country), might be exported through the Port of Durban (export country) to Japan (destination country). This is not South African economic activity per se, but economic activity that uses and pays for our infrastructure. The volumes are not significant compared with the rest of South African volumes, but as long as this remains, infrastructure capacity is required to handle this freight.

The SARS data was in some areas found to be rather incomplete or even declared wrongly or inconsistently. This might be considered as tax evasion methods, which stretches beyond the scope of this research. However, the SARS data proved to be valuable to fill in some of the gaps left by other datasets.

Now given that TNPA do not capture the contents of containers, but only bulk volumes, one could expect to complete the missing link through the SARS data. So if one considers citrus exports through Cape Town port in 2012 as one example, one finds the following details from different datasets:

- SARS reported 308 000 tons exported;
- TNPA reports bulk exports of 48 000 tons.

It can then be assumed that 260 000 tons was exported in reefer containers. However, if the Perishable Products Export Control Board (PPECB) data for this same time frame and port were consulted, it showed 280 000 tons of bulk. This shows a discrepancy of 20 000 tons or 6.5% that is difficult to hide or resolve given the magnitude of the difference and the organisations involved. The Citrus Growers Association (CGA) provides annual exports, but unfortunately does not provide details per port. The question that remains to be answered is which of these is correct. The error might be due to inaccurate assumptions made by various parties, such as the weight of a pallet of citrus, or the commodity classification from any of the datasets. Many similar instances and challenges were found in the SARS data, and these are discussed in more detail later.

5.4.5 TFR data

Transnet Freight Rail (TFR) data includes origin and destination elements that facilitate the understanding of hinterland influencers on the port infrastructure. The TFR market share for movement of full containers to and from the ports is low at 18% and 14% respectively. This data does contribute to some extent to this understanding, but does not provide extensive evidence. This detailed data covering the years from 2010 to 2014 was made available to the researcher during the study, with the following aspects included:

- Origin and destination stations linked to districts;
- Commodity details of freight or container volumes;
- Tonnes of freight shipped.

This data also provided a minimum value that could be used as a balancing and validation for total commodities at port level. For example, Port A cannot export less of Commodity X than what was moved to the port by rail, unless considerable storage capacity is available.

5.4.6 Case study: Citrus exported in 2014

To illustrate the process followed to combine all the datasets to understand one commodity in full it was decided to deconstruct one commodity exported over the quay wall for one year. Citrus is exported on an annual basis through various ports and across borders and was deemed a good example to illustrate the logic of combining the datasets. Citrus industry data is easily available and reported on a frequent basis by the Citrus Growers Association (CGA). For this example 2014 was chosen for the analysis and some of the values are shown in Figure 5.25, which is a partial repetition of the concept explained in Figure 5.18.

According to the CGA 2015 Annual Report, 150 260 989 cartons of 15 kg were exported in 2014 (Citrus Growers Association, 2015). This adds up to 1 728 915 tons of citrus exported across the quay wall and through border posts. The SARS dataset indicated 114 052 tonnes shipped by road and 1 417 tonnes by air transport, thus leaving 1 613 445 tonnes shipped across the quay wall. This information needs to be combined with the TNPA recorded bulk quay wall volumes of 240 434 tonnes through all ports. A subtraction of the bulk from the known quay wall volumes leaves about 1.44 million tonnes. Of this 81% is known from shipping line sample data, representing a total of 1.125 million tonnes. The remaining 317 000 tonnes were outside of the sample data and assumed to be in shipping lines not part of the sample. The sample can thus be inflated to accommodate for the known tonnes based on industry data from the CGA and the PPECB.

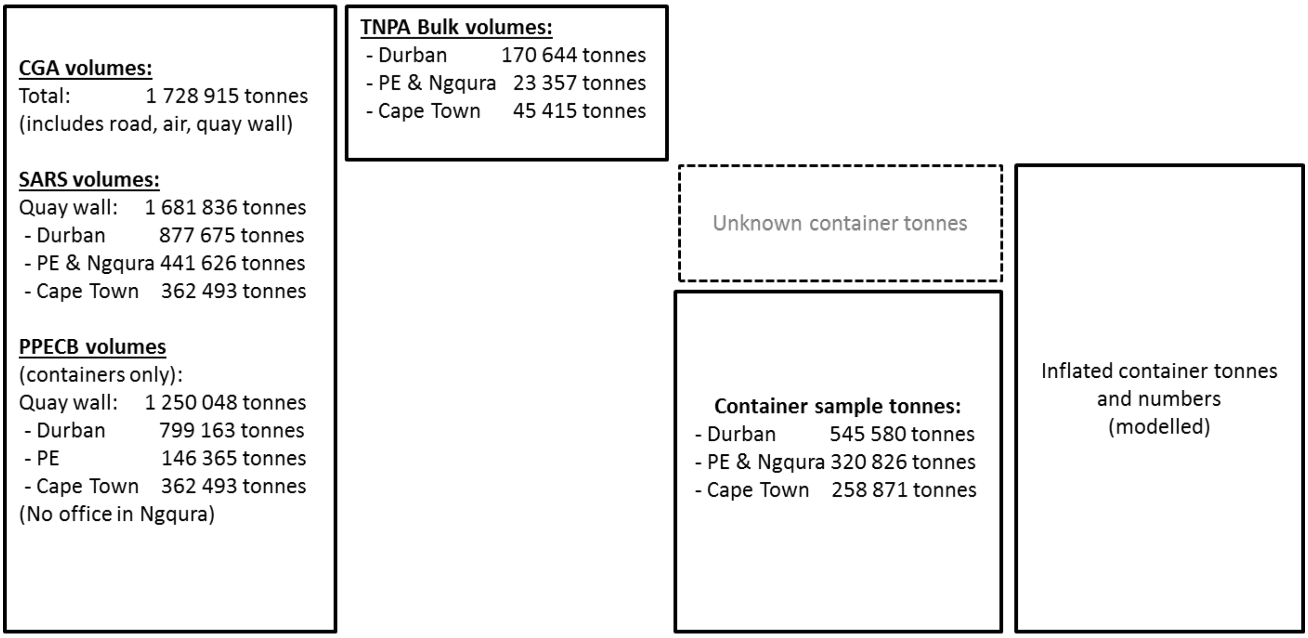

Figure 5.25: Citrus case study to illustrate the various volumes available from different datasets

Data from this 81% shipping line data sample and the PPECB that also provides container numbers can be used to calculate various input values for the container model for citrus as a commodity:

- The container physical types (similar across all ports):
  - Forty foot refrigerated = 99.88%
  - Twenty foot refrigerated = 0.12%
- The average weight per container type:
  - Forty foot refrigerated = 19.7 tons per forty foot
  - Twenty foot refrigerated = 16.5 tons per twenty foot
- Destination preference (3 largest destinations):
  - Europe: Durban 46%, Cape Town 27%, Port Elizabeth 27%
  - Middle East Asia: Durban 48%, Cape Town 19%, Port Elizabeth 33%
  - Asia: Durban 60%, Cape Town 8%, Port Elizabeth 32%

These values can be used to inform parameters and input values for the various container modelling typologies defined further in this dissertation. The following section will discuss how this detailed data has been analysed to determine further design requirements and parameters used in the content-based modelling framework later in this dissertation.

5.5 Parameters identified from analysing industry datasets

5.5.1 Ground rules for containerisation analysis

There are too many dimensions to all the datasets to graph in this dissertation. Some aspects can, however, be shown as illustrations. These datasets have been processed and values were used for 2014 as an example if not specified otherwise. The first year that shipping line datasets were obtained, 2009, has been a learning curve for both the project team and the shipping lines and had a low sample percentage. Due to some anomalies in the process, it was considered to rather exclude this year from the data analysis, and work with data from 2010–2014 only in comparison with similar years that the other sources made available. This provided trends over 5 years as input values.

In most of the examples the large and dedicated mining bulk commodities were excluded, since these commodities would and should probably never be containerised in significant volumes. So the commodities excluded were: coal exported as dry bulk through the Port of Richards Bay; iron ore exported as dry bulk through the Port of Saldanha; manganese exported as dry bulk through the Port of Port Elizabeth; and imported crude oil as liquid bulk through multiple South African ports.

5.5.2 Commodity classification decision

The analysis of the shipping line data for 2014 did not suggest that any additional commodities needed to be added to the existing FDM classification list. The latest changes to the commodity classification system described in section 2.2.3 already include inputs from the shipping line data. The current list of 83 commodities shown in Appendix A would suffice for the container modelling in the South African context.

5.5.3 Rate of commodity containerisation

Industry datasets provide total tonnes traded through various ports and TNPA provides data on bulk volumes per commodity and total containers handled by all the South African ports. From these datasets and the logic explained in Figure 5.18, a historic containerised percentage can be calculated for each commodity per year. Figure 5.26 shows the percentage of total freight containerised per port for the three largest container ports in South Africa. This is split into export and import values to indicate the differences.

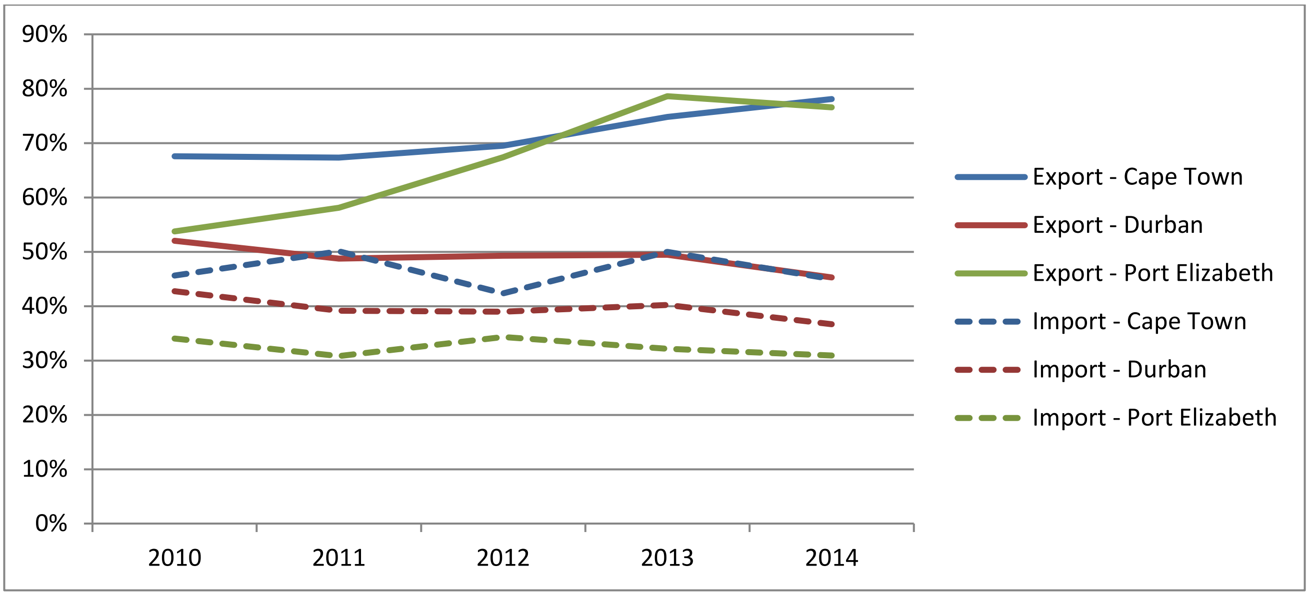

Figure 5.26: Containerisation percentage per port for three largest container ports in South Africa

The percentage of containerised freight exported through the Port of Cape Town has grown in five years from below 70% to close to 80%. The high volumes of fruit exported through this port have contributed significantly to this high percentage. The percentage for the Port of Cape Town imported containerised freight varies in a range between 40% and 50%. As seen in the TNPA volumes, the Port of Durban is the most significant container port, and showed a band of containerisation of 45–52% for exports and 37–43% for imports.

The Port of Elizabeth (combined with the Port of Ngqura) shows a fairly low level of import containerisation at 30–35%, but a very high export containerisation of 55–80%. The upward trend and high export containerisation in 2012 through 2014 is due to high containerised volumes of manganese, chrome and other mining exports that were sent through the Port of Port Elizabeth and the fairly new Port of Ngqura that is growing in preference on many shipping routes. These commodities are not the ideal to be transported in shipping containers. This phenomenon is caused by capacity limitations on both the rail lines from these mining areas, and the bulk export terminals. This capacity limitation drives freight owner behaviour towards road transport being preferred for these commodities in containers from the mine to the port and then being exported in this format. Once the capacity issues are addressed this might and probably should disappear from both South African roads and container shipments. This needs to be monitored continuously to establish future trends and patterns and isolate anomalies due to these capacity constraints.

In section 4.2.4 the adoption rate of freight containerisation and the maturity of the container concept were discussed. A number of illustrative S-curves indicating containerisation growth rates are shown in Figure 5.27 with the actual numbers shown for imported rice. In this example it can be seen that rice seems to be becoming more containerised over time and might strive to being 100% containerised in the future. A longer period of data will confirm this or might indicate that it reaches a different plateau altogether, like the S-curve, stopping at a lower ceiling of 60%. Some commodities have shown initial fast growth in containerisation, but are limited to a different ceiling than 100%. This could be due to the combination of sub-commodities where some of these can be containerised and the others not, thus leading to a collective containerisation of less than 100% achieved for that commodity group. In some cases due to this change an argument has been entertained in the past to divide these commodity groups into separate commodity groups. Some of this has been done, but some not.

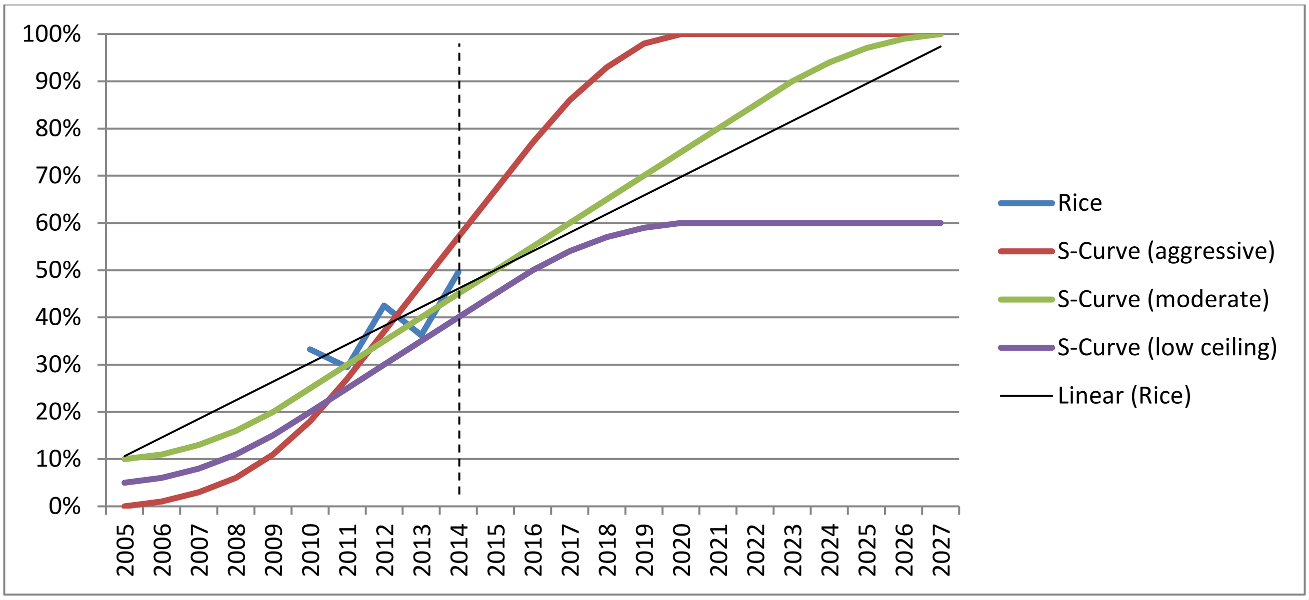

Figure 5.27: A typical S-curve indicating commodity containerisation growth for imported rice

Examples of the percentage containerised per mining commodity over the five years from 2010 to 2015 with the average over the time period are shown in Figure 5.28. More than a third of all the imported mining commodities have been close to 100% containerised over the years under study. Just less than a third have always been at or close to 0% containerised, while the rest of the commodities have been fluctuating significantly over the five-year period. The bottom third and top third are reasonably settled and one could expect that these commodities will remain at their respective 100% containerised and bulk preference positions, with these starting and ceiling values.

A commodity like gypsum, however, has an average of 45% over the five years, but it has been fairly volatile returning values of: 1%; 100%; 24%; 100%; and 2%. Thus no pattern or trend can be established to determine any of the desired three values for the three related parameters:

- a starting position is unclear;
- a speed of increase or decrease cannot be pinned down;
- no long term ceiling percentage can be determined.

Further analysis into the detailed data needs to be done. Table 5.3 shows that there are significant gypsum volumes exported in bulk through the Port of Durban in what seems to be every second year. Due to the limited detail included in the TNPA data, no destination or other trends can be picked up from the bulk imports seen for the Port of Durban in 2010, 2012 and 2014.

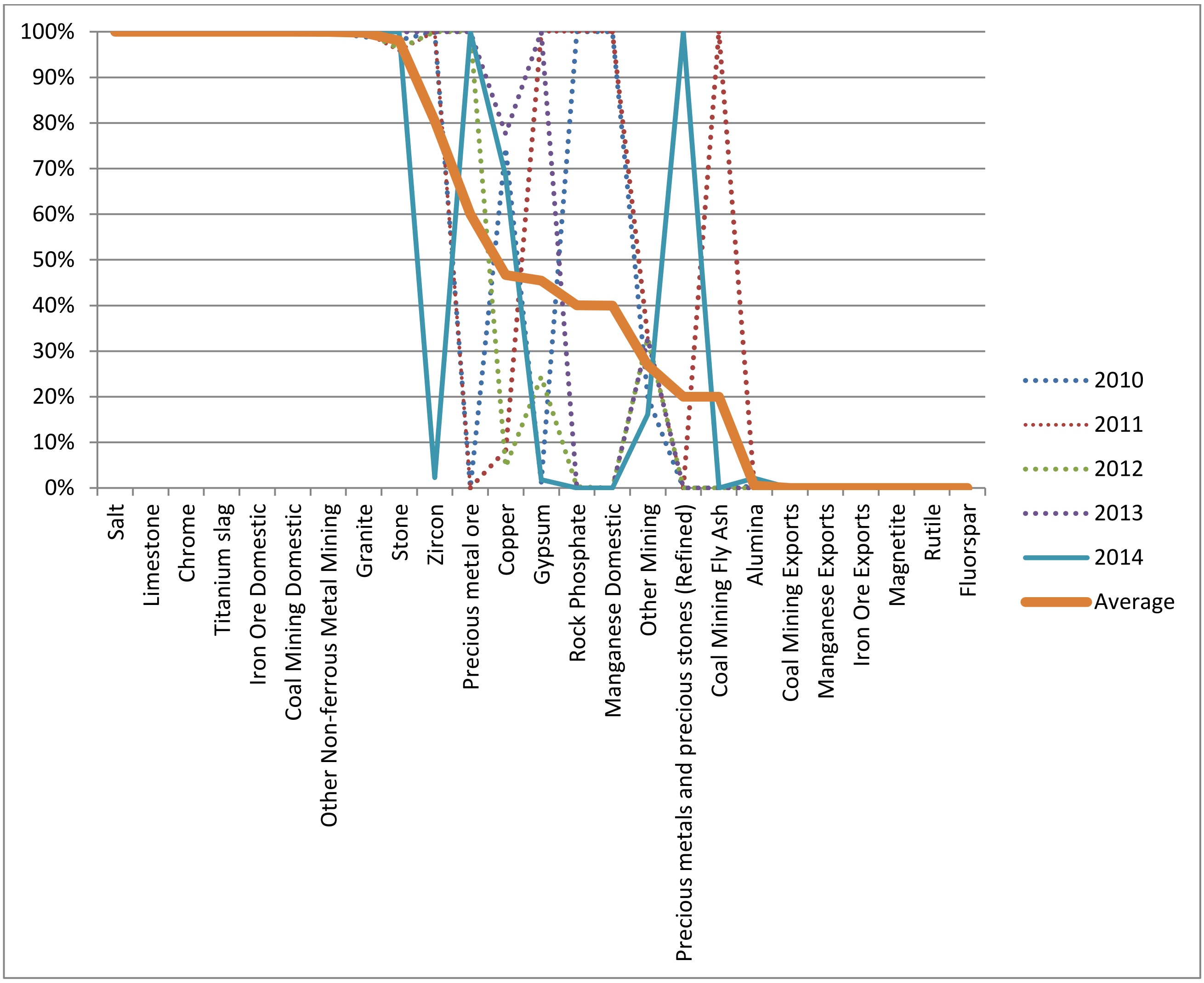

Figure 5.28: Comparative containerisation percentage for imported mining commodity groups

What can be learned from this data is that all imports of gypsum through the Ports of Cape Town and Port Elizabeth have been containerised. The Port of Port Elizabeth only once had 61 tonnes imported from Thailand, and this could probably have been due to a single ship routing or a port congestion issue. It can be concluded that gypsum would have a 100% containerised starting position and upper ceiling for both these ports.

Table 5.3: Breakdown of imported gypsum tonnes per port for bulk and containerised

Port	Source	2010	2011	2012	2013	2014
Cape Town	Bulk	-	-	-	-	-
	TEU	33	178	468	124	872
	Total	**33**	**178**	**468**	**124**	**872**
Durban	Bulk	32 901	-	5 504	-	102 084
	TEU	377	703	1 306	1 663	1 012
	Total	**33 278**	**703**	**6 810**	**1 663**	**103 096**
Port Elizabeth	Bulk	-	-	-	-	-
	TEU	-	61	-	-	-
	Total	**-**	**61**	**-**	**-**	**-**

Focusing on the Port of Durban investigation shows that a reasonably consistent, slightly growing volume of containerised gypsum has been imported in containers. The shipping line data indicate that these volumes came primarily from Pakistan (51%) and Germany (33%) in 2010; from China (28%) and Iran (45%) in 2011; from China (47%) and Iran (44%) in 2012; with a shift to Germany (67%) and France (22%) since 2013. All of these tonnes have been 100% containerised. A containerised volume of gypsum imports can be derived from this data and the question might be if the gypsum that is imported in bulk vs that imported in containers are not of two distinct types and grades. Unfortunately, no further knowledge is available on the origin and destination of the bulk imported gypsum volumes to provide insight into this matter.

Figure 5.29 shows the same breakdown of percentage containerised, but for imported manufactured goods. Almost half of all the commodities have been 100% containerised. One can also identify a section close to 100% that has been less volatile and seems to be approaching 100% containerisation. For another group of commodities the last year, 2014 shows a recognisably higher percentage than the average over the five years, and thus for these commodities it can be derived that a growth towards 100% containerisation is most likely within the short- to medium-term forecast period.

A similar analysis had to be done for each commodity for each port to understand the trends over each year. Often the destination views or detailed commodity descriptions from the shipping line data provided valuable inputs that helped to understand anomalies or confirm assumptions that had to be made due to a lack of inputs from other datasets. Each commodity is at a different place on the S-Curve explained in Figure 5.27, and this position might be influenced by the origin-destination port combination or the South African port involved. The complete and detailed analysis had to be done for all seven ports, for all port origin-destination combinations, and for all 83 commodities used by Transnet Group planning. This was done to determine the starting values and forecast values for container modelling. A project team of analysts and researchers assisted with the bulk of the analysis under the supervision of the author. By analysing the current trends for each commodity, port origin and destination combinations and unique South African Port trends, various options are available to model the containerisation percentage over the forecast horizon.

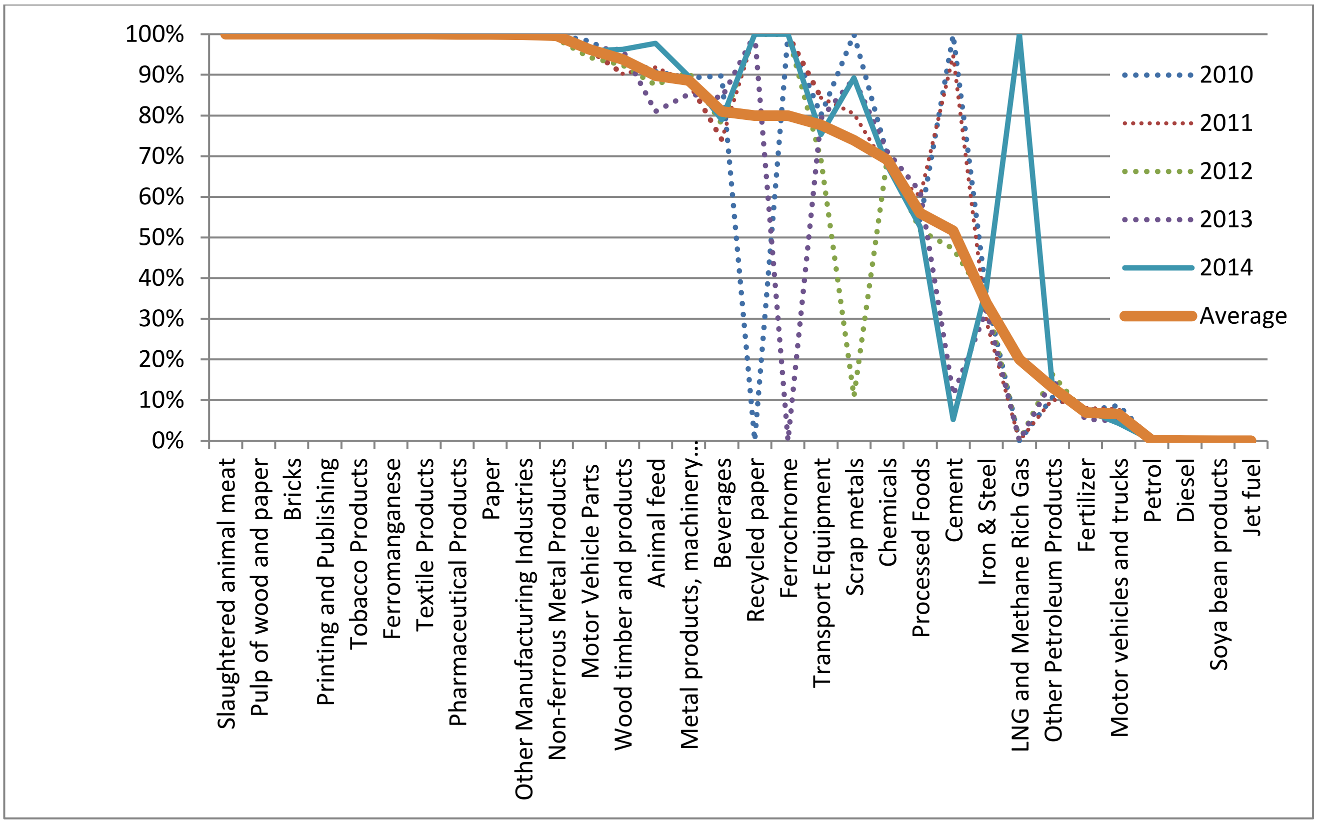

Figure 5.29: Comparative containerisation percentage for imported manufactured commodity groups

Given this detail a number of modelling aspects regarding the percentage of containerisation need to be established. The percentages per commodity are expected to change (mostly increase) over the forecast period, and individual commodity assumptions need to be researched on three aspects:

- The *starting position:* A containerisation percentage for each commodity and port combination was determined from the latest available bulk and containerised freight tonnes. In volatile cases an average was used; for stable trends the last base-year value was used as a starting point.
- The *speed of increase/decrease* in containerisation for each commodity and port combination: The historic analysis to date has indicated a default value of 3% increase on the currently containerised percentage (i.e. multiply by 1.03, not +3%) being accurate in most cases. Some individual cases with exceptional growth or decrease have been identified and different rates are applied. This analysis process is continuing.
- The *containerisation ceiling percentage* for each commodity per port: Many commodities will most likely not be containerised 100% on long-term forecasts, but achieve a lower ceiling percentage at some stage in the near future. This ceiling percentage needs to be researched and defined per commodity per port. Historically 100% has been the default option for most commodities, with limited exceptions. This needs to be further analysed. While bulk reefer and bulk general ships are still present in the global fleet, some commodities that could be 100% containerised could remain at less than 100%.

Provision needs to be made in the modelling approach for these three parameters and values for them over the forecast horizon. Only more data and time will allow these to be accurately defined. Further research needs to be done to determine values to be used in future modelling forecasts. However, three parameters have been identified: starting position of containerisation, annual rate of change in containerisation, and the ceiling percentage of containerisation. A section of the input data used for analysis is shown in Appendix B.

5.5.4 The changing weight of the freight within containers

The previous section discussed how much of each commodity would be imported and exported in containers versus bulk shipments. The next objective would be to understand how much of each commodity is packed into each container. The weight per container unit can be derived from the shipping line data per commodity per container type per port combination. The weight per container unit should be defined separately per physical type of container that is used per commodity per port.

From the shipping line data the weight per container for each commodity for imports and exports can be carefully derived over the five years. By using this weight per container, the number of full containers over the quay wall can be determined by dividing the total volume (in tonnes) of imports and exports for each commodity by this predetermined weight per container for each commodity for imports and exports respectively. Although this is a lengthy exercise with all the dimensions possible, not a lot of in-depth analysis is required.

A number of anomalies have been found in the data with extremely heavy or light containers, especially with very small and/or infrequent shipments of specific commodities to specific ports. These were analysed to understand whether this is caused by inaccurate data, inaccurate commodity classification, and outliers due to unique circumstances or if it was valid data that needed to be included. In some instances it was one light container being partially filled due to a low demand at one remote location. In other cases it was extremely heavy 20 foot containers where the container size was potentially incorrect and should for all practical reasons have been a 40 foot container.

A fairly stable denominator has been determined for most commodities. However, on a national import and export level a trend has been identified where export containers are becoming heavier over time and import containers lighter. This trend is shown in Figure 5.30. If persisting over the forecast term, this will imply more containers being needed for the same volume of goods for imports, and less for exports. The last year in the export data showed the first decline in weight per TEU for export containers. This breaks the trend and needs to be further investigated to be understood and to make the right decisions in terms of modelling values in the long term. Detail per commodity is important to analyse specific trends per commodity.

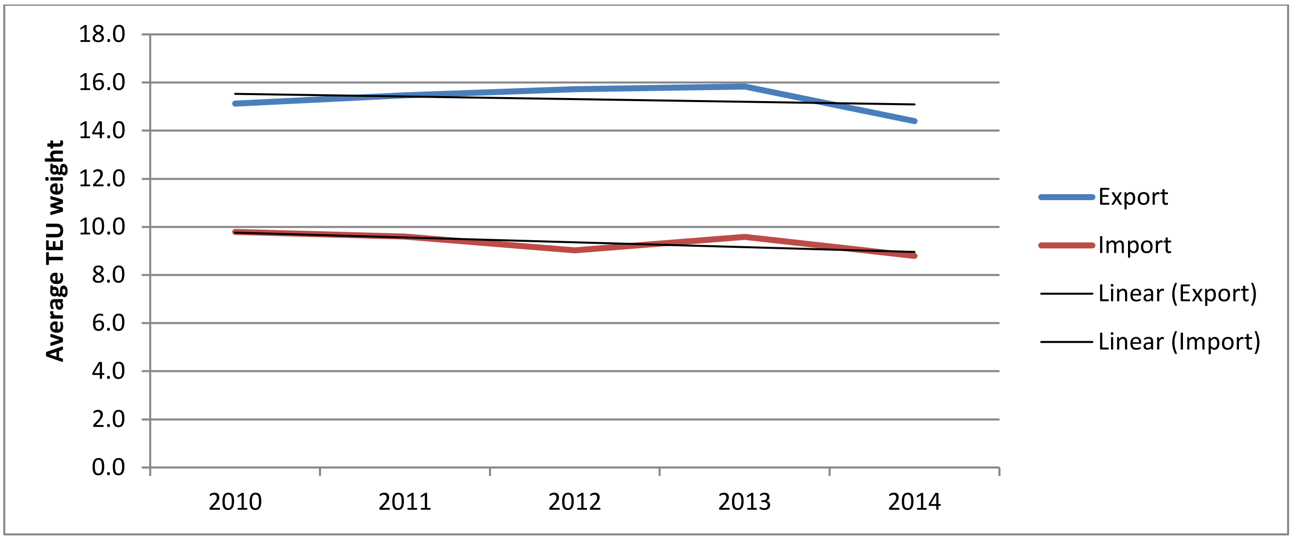

Figure 5.30: Average weight per TEU for export and import containers

Although this trend does not have an immediate impact, it will impact a 30-year forecast if significant changes occur over this extended period of time. The trend needs to be carefully monitored to see how this phenomenon will develop, and drivers need to be determined and analysed. This will ensure the accuracy of long-term forecasts by making adjustments over the forecast term per commodity where appropriate.

Industry players have this tendency to pack more products into each container to achieve better economies of scale and thus reduce unit transport cost. It could also just be a trend that is due to the composition of South Africa's total imports and exports changing towards lighter and heavier commodities respectively overall. If this is true, the individual weights per container per commodity might actually not be changing. For example, if South Africa continues to export heavy agriculture and mining commodities in containers and few lightweight manufactured goods are exported, the average weight of export containers will remain relatively high. Similarly, importing more electronic and lightweight plastic manufactured goods from Asia will continue to reduce the average weight of imported containers.

To illustrate the method of analysis, the focus would be on '*iron and steel*' as a commodity. Figure 5.31 shows the trends for tonnes, the number of TEUs and the average weight per TEU from the shipping line sample data.

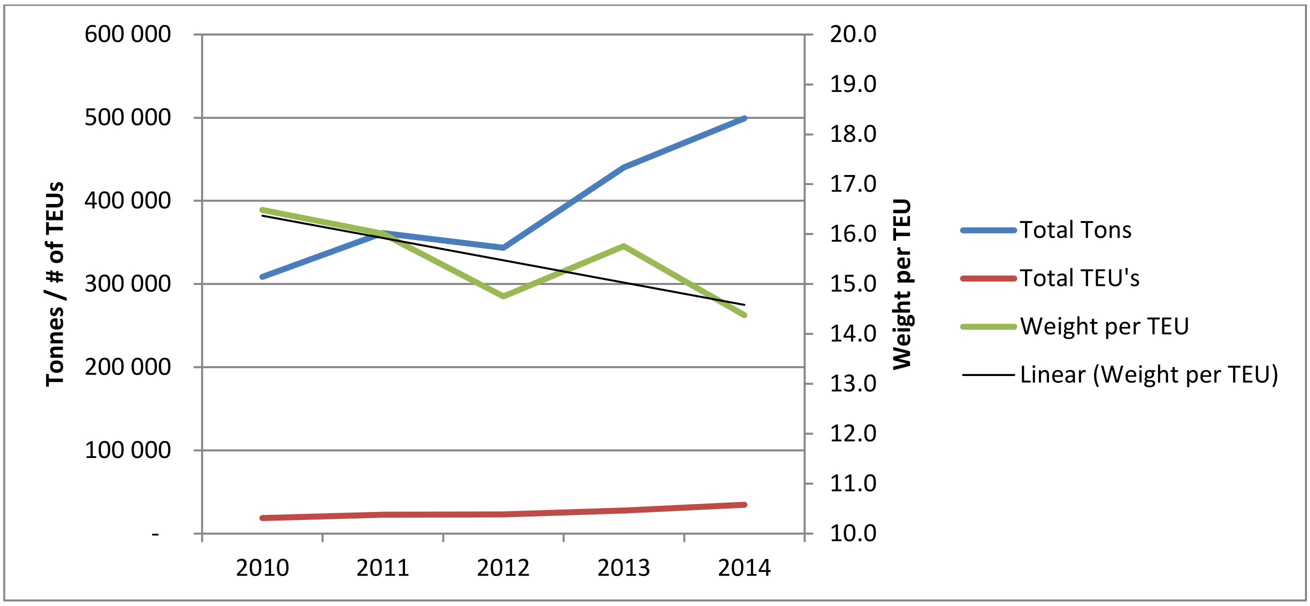

Figure 5.31: Iron and steel imports: Tonnes, TEUs and weight per TEU per year

The shipping line dataset recorded 85 different countries from which South Africa imported iron and steel-related products that can be classified as part of this commodity grouping. A few statistics and calculations from the shipping line dataset for *iron and steel products* (cumulative over all five data years):

- Total TEU 127 232
- Total tonnes in TEU 1 952 798
- Average weight per TEU 15.3 tonnes per TEU
- Maximum weight per TEU 26.7 tonnes per TEU
- Minimum weight per TEU 2.3 tonnes per TEU

The minimum weight per TEU was found to be a once-off shipment of 884 TEUs from Kuwait in 2012, imported through the Port of Port Elizabeth that the shipping line described as '*Empty tanks and containers of steel*'. This affects the trend in 2012 for this port, as can be seen in Figure 5.32. The maximum weight was 22 TEUs imported from Russia through the Port of Durban in 2010 with a description of '*Iron sheet plates*'.

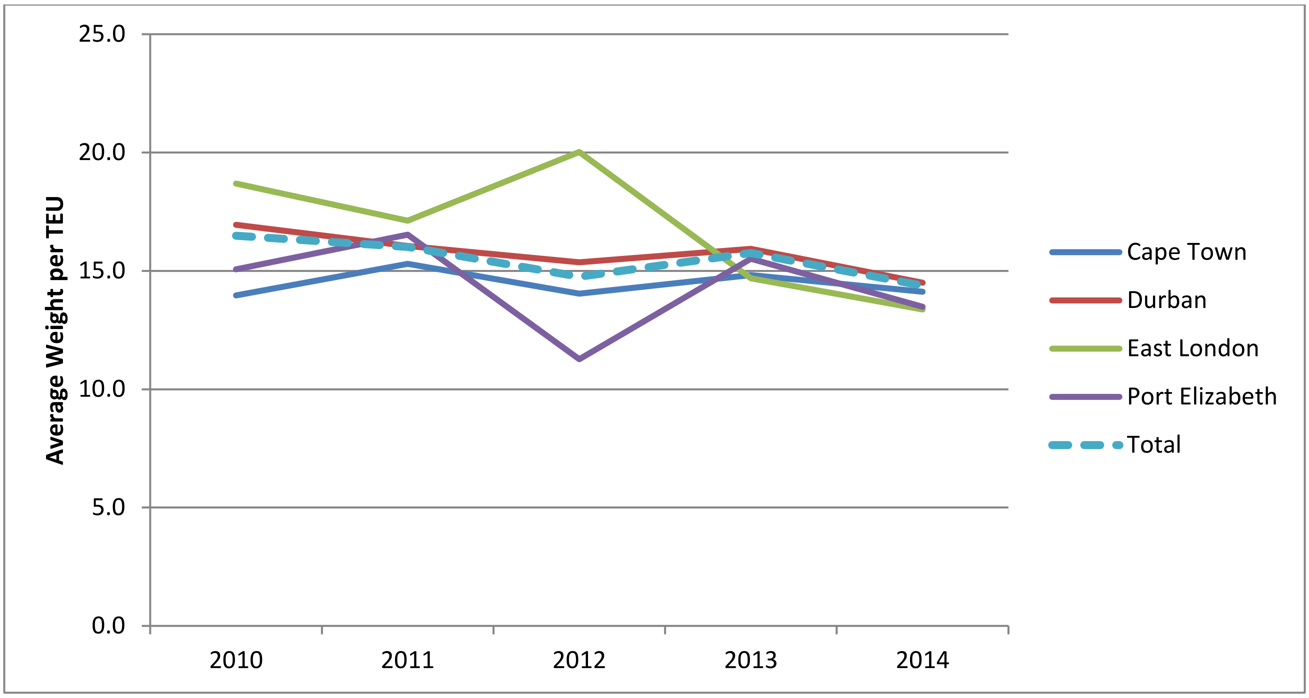

Figure 5.32: Average weight per TEU for 'iron and steel' imports per port

Iron and steel commodities across South African ports follow a fairly similar pattern. The only exceptions are the lighter containers in the Port of Port Elizabeth and the heavier containers in the Port of East London, both in 2012. The lighter containers in the former of the two have been explained above due to the empty steel tanks being imported in containers. The heavier containers in 2012 through the Port of East London were 39 containers from Malaysia described as '*Iron, steel, iron and steel articles, metal*' with an average weight of 22.2 tonnes per TEU. This made up 57% of that year's total shipment for this port and thus contributed to the heavier average. The extent of detail within the shipping line data can lead to too many variables and thus too many options which are not practical to include in a container port forecasting model. To illustrate the extent: there is a total of 194 combinations of origin country and South African destination port for all imports of only the *iron and steel* commodity. An average weight per year with trends can be calculated for each of these combinations.

Another dimension to consider is the direction aspect, i.e. import and export freight flows. Imports have been discussed above, but how does this differ for exports of *iron & steel* as a commodity? Interestingly the exports of this commodity follow roughly the same annual trend as for imports, but is about 10–15% heavier than for imported iron and steel products. Also a distinctly different average weight was recorded per destination country. Figure 5.33 shows how significantly the average weight per TEU differs for the highest volume export destinations for *iron and steel* products.

The wide range of average weights per TEU shown in this figure is due to the different composition of items for these destinations that are classified as iron and steel. The container content recorded for the United States (average of 17.3 tonnes per TEU), China (average of 21 tonnes per TEU) and Germany (average of 22.3 tonnes per TEU) are dominated by descriptions such as '*sheets, rolls of iron and stainless steel'* that are still in a work-in-process format designed for further processing. These items are considerably heavier formats of the commodity than the '*products and articles of iron, steel and metal*' that are final components or products mostly recorded as being exported to Japan (average of 7.4 tonnes per TEU). These differences seem to be consistent over the available years of data, and one could accept that this trend will continue until future data suggests otherwise.

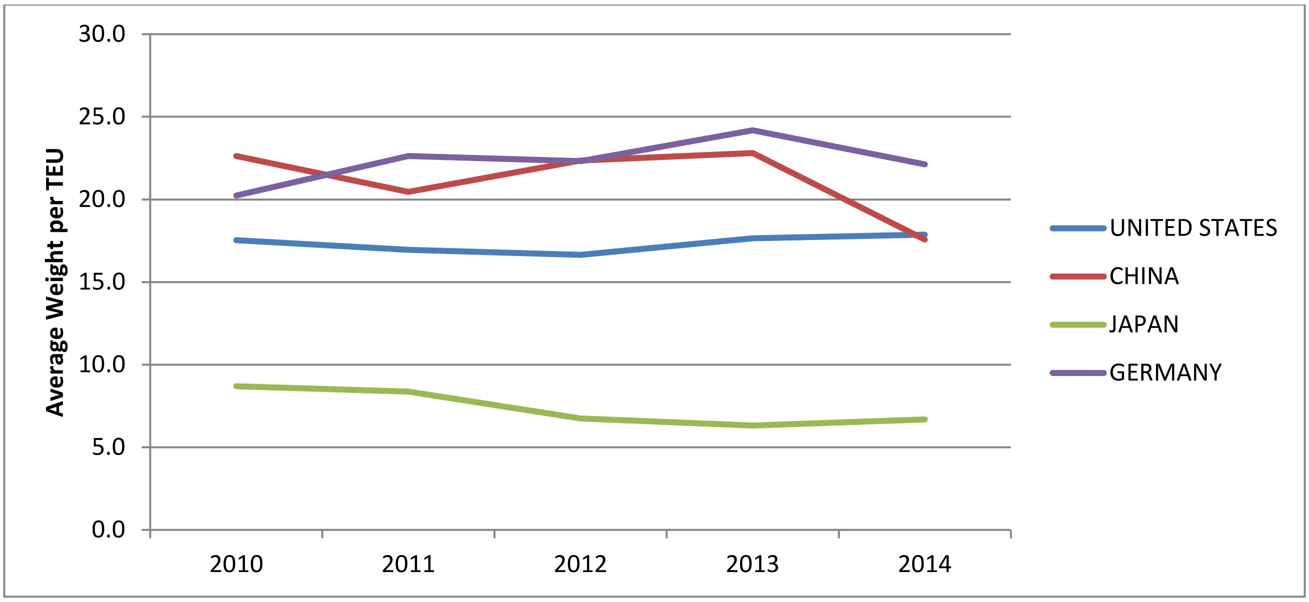

Figure 5.33: South African iron and steel export weight per TEU for the top 4 export destinations

Thus, two new aspects emerge from the import and export dataset for manufactured iron and steel products. Firstly, a different weight per TEU is possible for imported and exported products, and secondly a different average weight per TEU might exist for specific route, i.e. origin and destination combinations.

The other 82 commodities were also considered and analysed as separate entities to confirm whether these dimensions are true for them as well. In most cases it is sufficient for modelling purposes to use only a South African national average weight for imports and exports per commodity, thus 166 values and trends need to be populated. Provision needs to be made for exceptions based on direction; changes in weight per TEU over time; the limits that are achievable for specific commodities/destinations; the speed at which this weight can change, and if specific ports have independent values and trends. Within these aspects it is assumed that freight owners would always attempt to pack as much as possible into every single container to reduce the transport cost per unit, but within the limitations of transport regulations, such as physical container dimensions and strengths, crane lifting weight restrictions, and road and rail vehicle axle weight limits for secondary transport.

The main concepts to consider with the weight of products packed into each container are the multiple variables discussed above. To cater for all these concepts experienced in the datasets, the following parameters could be included in the modelling framework:

- Weight per TEU (base): Based on historical weight per TEU a starting value of tonnes per TEU will be proposed for the modelling period.
- Weight per TEU (ceiling): Based on historical weight values found per TEU on different routes and ports a maximum value can be determined that containers for a commodity could move towards over time.
- Weight per TEU (density potential): Each product has a density profile that determines the maximum percentage that it can increase in weight per TEU. This can be limited by the nature of the product within the available space, or aspects such as airflow and refrigeration capacity requirements for refrigerated products. The density potential could be similar or even more than the Weight per TEU (ceiling) value above.
- Weight per TEU (period): Once a base and a ceiling weight are determined, the question is how fast a commodity would change to reach the ceiling value. A period needs to be determined over which each commodity would change to the maximum weight.

- Port independence: This parameter determines whether weight per TEU could reasonably differ at various ports for each commodity. If this is the case, the complexity for these commodities would increase.
- Direction independence: This parameter distinguishes whether weight per TEU could reasonably differ for imports and exports. The composition of commodities imported might vary, leading to different values and adding to complexity.
- Trade partner independence**:** This parameter distinguishes whether weight per TEU could reasonably differ for trade partners. Again this would add to both complexity and accuracy.

The level of complexity included if all six parameters are applicable might not be practical to implement across the model and simplification might be required. However, if the variations seen in the data are considered, these parameters have significant and far-reaching implications and as such cannot be ignored for accurate forecasting results.

5.5.5 Container physical type

Transnet port infrastructure planners indicated during discussions that they would prefer to plan for a breakdown of container types by using the following categories:

- Normal Twenty Foot Unit (NTFU)
- Normal Forty Foot Unit (NFFU)
- Normal High cube Forty Foot Unit (HFFU)
- Open Top Twenty Foot Unit (OTFU)
- Irregular sized Twenty Foot Unit (ITFU)
- Tanktainer (twenty foot) (TANK)
- Flexitank (twenty foot) (FANK)
- Reefer Twenty Foot Unit (RTFU)
- Reefer Forty Foot Unit (RFFU)

These categories are also the types used by Drewry and other international shipping authorities in their planning and reporting of the global container population. Drewry provides regular reports on the current world container population and changes to that pattern. These reports are very expensive and were not available to the author. Current available data from TNPA, shipping lines or any other source do not provide any insight into this level of detail.

Port infrastructure planners are recently more interested in the type of containers that need to be handled, since this dictates the specifications of the required investment in quay wall infrastructure at container terminals. Although the worldwide trend might be to move increasingly to forty foot high cube containers, the nature of many commodities traded in and out of South African ports still prefer or dictate twenty foot containers to be used more frequently.

The shipping line datasets included the split between twenty foot and forty foot containers. This split has been done based on tonnes in the containers. The split based on the tonnes in containers are shown for imports and for exports in Figure 5.34 and Figure 5.35.

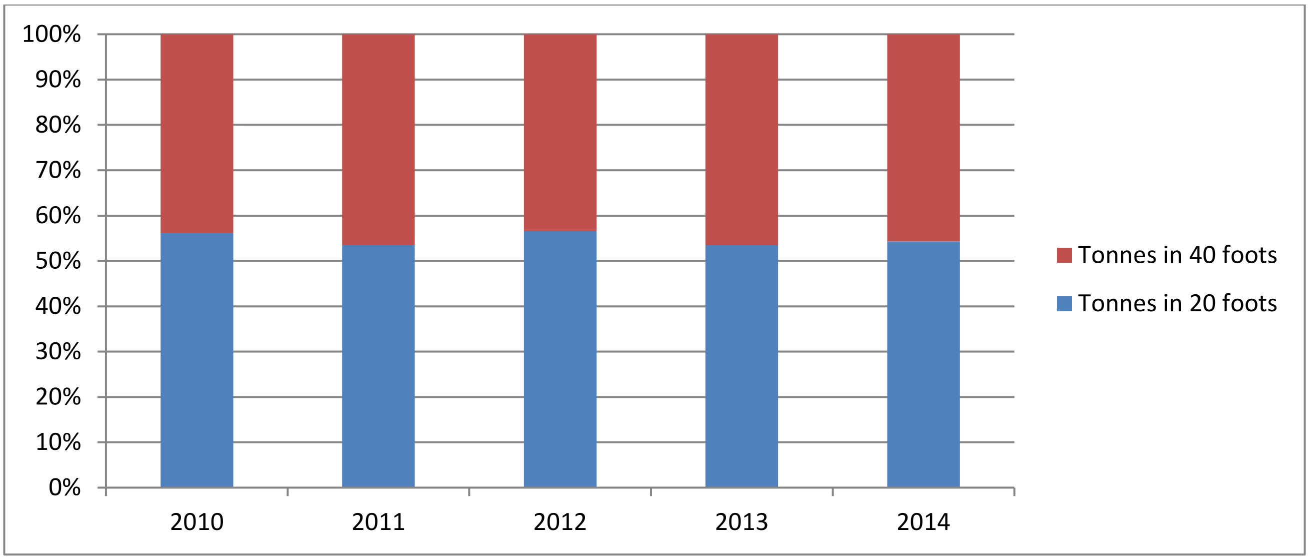

Figure 5.34: Split between twenty foot and forty foot imported containers in South Africa

The split for imported containers has not followed a noticeable trend, but seem to be fairly stable in the region of 53–57% for twenty foot containers and 43–47% for forty foot containers. This will be monitored for future changes, but provides a value for the split between these two container types.

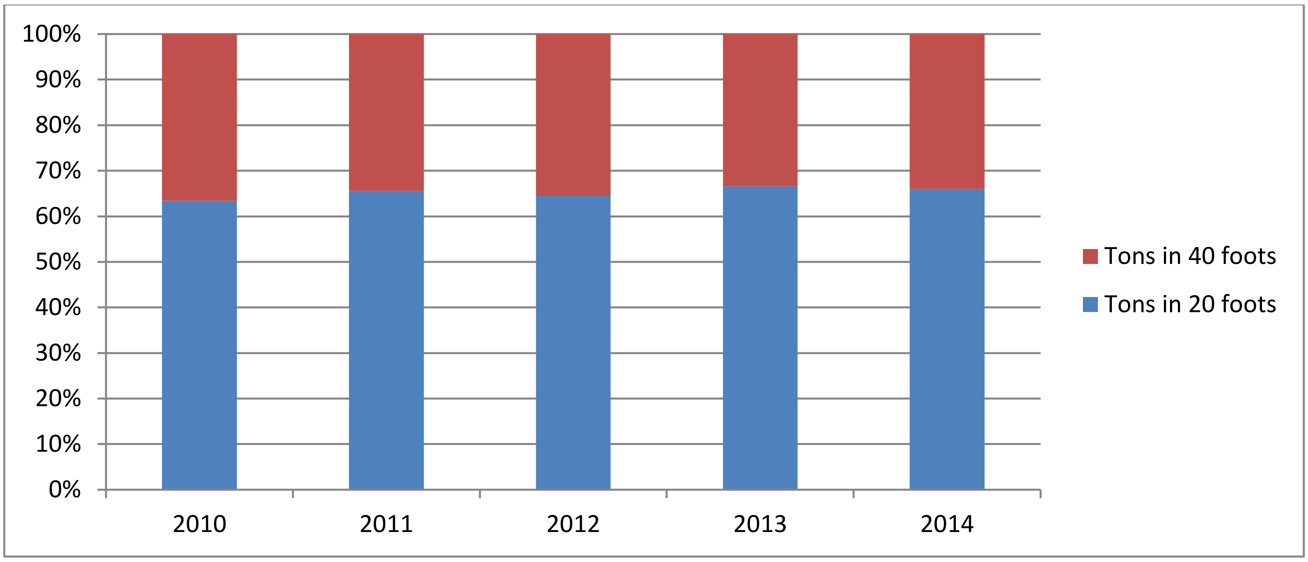

Figure 5.35: Split between twenty foot and forty foot exported containers in South Africa

The split for exported containers has also not followed a noticeable trend, but seems to be fairly stable in the region of 63–67% for twenty foot containers and 33–37% for forty foot containers. This is in a different range than for imported containers and needs to be monitored for future changes. The literature review indicated that a worldwide trend exists to move towards forty foot containers. The main driver for this is that it requires one lift to load and offload for the same goods whereas two twenty foot containers require two lifts. Freight owners are charged per container lift, and port operators often measure their efficiencies on TEUs per hour. With each mode transfer, the handling is thus reduced, as is the subsequent handling cost. For the same reason high cube forty foot containers are preferred vs standard height forty foot containers. This is an aspect to analyse further during the survey and focus group discussions.

The detail of this division between twenty foot and forty foot containers is available specific per commodity and per port. Modelling decisions can thus be made on this level of detail. Since 2012 some of the shipping line datasets introduced a split between container types indicating categories for: reefer, tank and dry. Here a 'dry' container indicates a general purpose container that is not refrigerated and is not a tank container. This enabled analyses for the detailed physical type breakdown into both twenty vs forty foot containers and the numbers for reefer, tanktainers and non-conventional containers. Reefer containers were used specific to commodities that are perishables.

Once this was analysed a number of patterns and trends were seen for specific commodity groups that on this basis could be grouped further into families that use the same physical container types. For example, perishable products would use different sizes of reefer containers based on their packaged weight, where some fruits would be too heavy per packaged pallet for forty foot containers, while other fruits are light enough to use forty foot high cube containers. The concept of physical type families provides for a lower modelling complexity than trying to be specific for all 83 commodities over all the forecast years. The six physical type families have been defined as:

- General Containerised (GC);
- Partly Refrigerated (PR);
- Refrigerated Only (RO);
- Refrigerated liquids (RL);
- Liquids only (LO); and
- Liquids mixed (LM).

Sufficient input data is available to define modelling values for these six physical type families. These can then be linked to the commodity groups and used to model container physical types as required by port infrastructure planners. More detail on this is discussed in section 6.3.4 and Appendix F.

The cross section of container physical types and weight per container provides another interesting insight. One might expect the average weight of forty foot containers to be double that of twenty foot containers for the same commodity. A number of examples show this not to be true even for the same origin-destination combinations. In most of these cases the average weight for a twenty foot was more than double the average weight for forty foot containers. It seems as if forty foot containers are packed lighter than twenty foot containers. It might be related to the container's physical strength in that a forty foot container might structurally collapse in the middle due to excessive weight, especially for some of the heavier mining commodities. The logic here needs to be understood, and was included in the survey and focus group discussion agenda. This might lead to a parameter where different weight requirements need to be specified not per container in general but per physical container type. This will increase the complexity, but also the accuracy.

5.5.6 Trade partner trends in container growth, commodity growth, port preference

The shipping line datasets provide invaluable inputs regarding trade partner trends in commodity growth, port preference and commodity containerisation specific to trade partners. These aspects need to be considered with forecasting container volumes, although they cannot always be directly implemented in the modelling process. Some of the aspects provide input information that needs to be shared with key partners like economists that can utilise the detail to provide more accurate inputs for forecast years.

The shipping line datasets provide information on historic trends of trading specific commodities between South Africa and multiple individual countries. Economists can use these as inputs in their econometric models to predict long-term growth or decline in specific commodity groups.

Another aspect the data provides is a view on port preference that specific commodity and country combinations have for both import and export. Although the port preference is more an effect of shipping line route decisions, than a leading indicator, it does provide trends and patterns that show specific preferences. For example, a significant portion of automotive components imported from Europe goes via the Port of Cape Town, whereas most automotive components from the East will go via the Port of Durban. As mentioned, it indicates the preferred shipping routes from shipping lines visiting one specific port in South Africa, and then returning on its route.

The last informative trade partner aspect is containerisation of commodity country combinations. Several examples were found of countries that had no containerisation, but traded in bulk and then a sudden shift towards containerisation occurs. The focus group participants provided an explanation that they often trade with specific customers that do not have the facilities or infrastructure at their ports or factories to handle containers. Once this infrastructure was put in place a rapid shift occurred. The same comment was made for changes from twenty foot to forty foot containers due to infrastructure or volume changes. These historic patterns provide valuable inputs and once they happen, port planners can change variables and input values for future trade for these commodity-country combinations.

Port planners need to plan on analysing the historic trends and then provide feedback to economists on the current trade trends, in order for them to incorporate this into their forecasts that are used in the FDM.

5.5.7 Secondary research parameters

5.5.7.1 Transhipped containers per port

The only dataset that provided any insight into transhipped containers is the TNPA summarised data. The TNPA container datasets described in section 5.3 provided insight into the full and empty transhipped containers through the South African ports. Figure 5.36 shows the transhipped container volumes for the top four container ports in South Africa.

The total transhipment volumes seem to be fairly volatile with a 20% difference recorded from year to year in more than one instance. It seems as if the Port of Ngqura is replacing the Port of Durban as the preferred transhipment port with a significant volume split away from the Port of Durban to the Port of Ngqura. The Port of Durban receives the bulk of the container ships visiting South Africa, which explains the large amount of transhipment also done by these visiting ships.

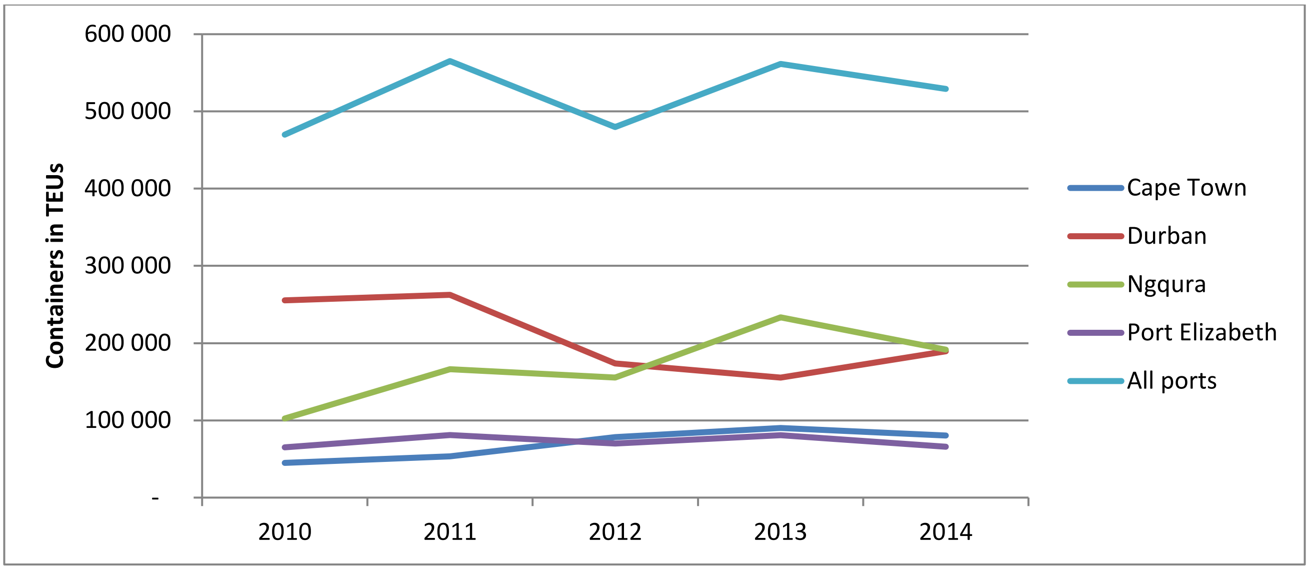

Figure 5.36: Transhipped containers per port (Source: TNPA dataset)

A strategy by Transnet to target transhipments at the Port of Ngqura is clearly paying off, but if the percentage of transhipped containers is reviewed per port, it shows in Figure 5.37 that many ships stopping at the Ports of Ngqura and Port Elizabeth are loading or offloading a significant portion of transhipped containers. This is close to 40% of full containers for both ports. The economic activity around these two ports is limited as compared to the Port of Durban, and the distance to Gauteng does not justify the additional road or rail transport cost for Gauteng freight to be channelled via these two ports. Whether container ships will in the long term continue with this practice is to be monitored.

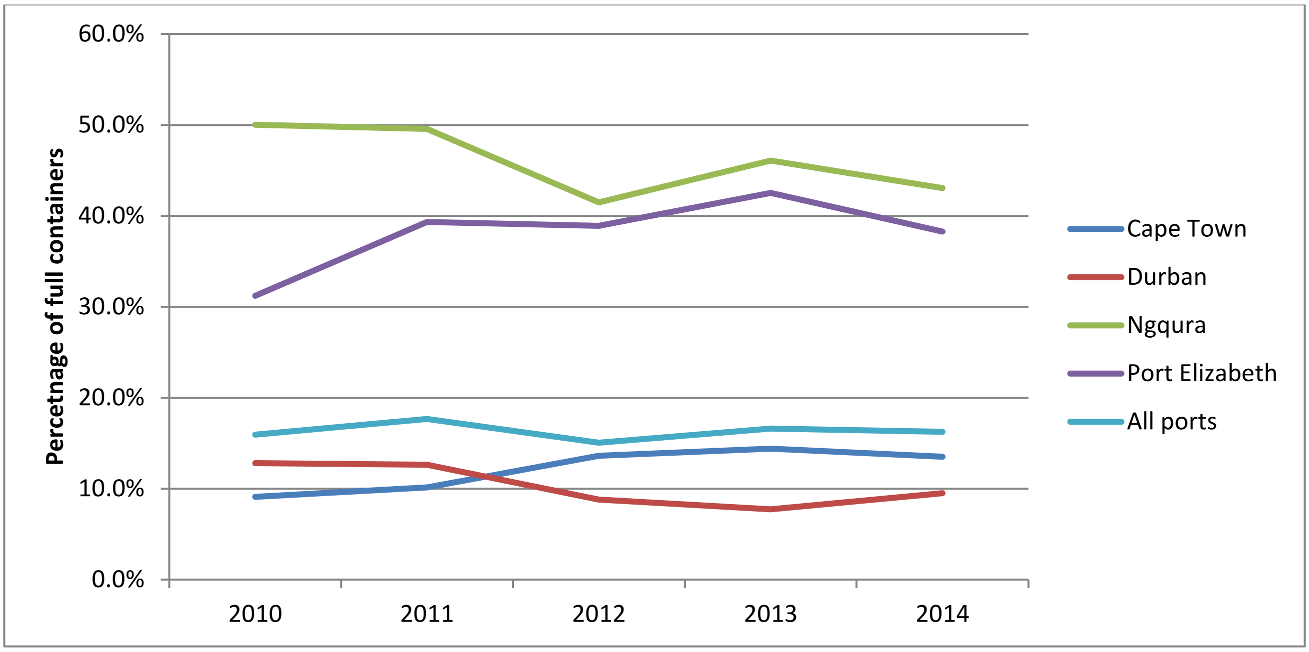

Figure 5.37: Transhipped containers as a percentage of full containers per port (Source: TNPA dataset)

The literature study has shown that transhipments seem to be levelling off at 25% of full containers globally. The South African transhipment contribution to port volumes varied between 15% and 18% of full containers for all ports over the time period from 2010 to 2014. This lower than global outcome might be ascribed to our southern hemisphere ports not being on high volume shipping routes like the Europe, Asia North America shipping routes. Thus due to less global trade passing the South African coastline, lower transhipments are experienced.

One way to forecast transhipped containers would be to determine trends for the percentage values per port and just use these as forecasts. A simple and easy approach to implement, but this might be flawed in its simplicity similar to the method of using a GDP forecast for full port container numbers.

A more complex approach might be to also consider the content of containerised transhipped containers and model this. That would be attempting to do a global version of the marine deep-sea container model segment proposed in section 8.2 and determine which of all these international trade flows would be feasible for natural and strategic transhipments at South African ports. This would be a much more complicated model requiring a higher level of detail that might be available from shipping line datasets if they can be obtained. Whether this effort will provide a significant improvement over and above the easier method is to be discussed to some extent later in the dissertation, but it is much too complex to include.

5.5.7.2 Empty containers per port

The literature indicated that empty container movements across quay walls have levelled off worldwide at 17% of the number of full TEUs. The TNPA data shows that the imported empty containers vary between

8% and 12% of full containers, while exported empty containers vary between 17% and 21%. South Africa is thus a net exporter of empty containers if one can call it that. This is the net effect of the exported commodities being mostly refrigerated agricultural products and bulk mining commodities, while a struggling manufacturing sector leads to large-scale containerised manufactured items being imported. The quay wall difference will remain as is as long as the manufacturing sector does not see a turnaround in South Africa.

Another aspect that contributes to empty container movements is the supply and demand of specific physical container types that might not be in balance. An example would be the demand for reefer containers before the South African fruit export season starts.

Empty containers are a function of quay wall, hinterland and domestic full container movements. Thus, the empty container model segment cannot be completed in isolation, but needs to integrate and interact with the marine deep-sea, marine coastal, and domestic container model segments. The literature review also highlighted the packing and unpacking of containers at or close to the port as a large scale influence. This needs to be better understood to develop a full-scale model that can accurately predict the movement of empty containers across quay walls, into the hinterland and domestically. When considering inputs and aspects from a number of the previous sections, the following modelling drivers can be derived:

- The destination of import full containers;
- The origin of export full containers;
- Unpacking/packing decision related to full containers landed/shipped;
- Physical type plays a significant role;
- Seasonality plays a significant role;
- Import/export volume balance.

These are elements where freight owners can assist by providing insight into how they make their decisions and how these decisions will be influenced in the future. The survey questions and focus group discussions will provide valuable inputs in this regard.

5.6 Design requirements identified in this chapter

Table 5.4 motivates the design requirements identified in analysing the shipping line data from this chapter. The data analysis confirms most of the functional requirements already identified leading up to this chapter. The data analysis also provides valuable starting values and often a five-year trend as input values for these functional requirements (modelling parameters).

Table 5.4: Design requirements identified in Chapter 5 (numbering continued from Table 4.6)

Req. ID	Requirement	Motivation	Quay wall extent
F2	Percentage containerisation	Introduced in Chapter 2, repeated in Chapters 3 and 4. The cross section of shipping line container content, TNPA bulk volumes and industry body data provide a richness of information to deduct a containerisation percentage per commodity per port per direction per destination country.	Marine deep-sea

Req. ID	Requirement	Motivation	Quay wall extent
F5	Container physical types	Introduced in Chapter 2 (as User requirement), repeated in Chapter 4 as functional requirement. Various container physical types are available. Shipping line data is sparse on details of all the container physical types and mostly only distinguishes between 20 foot and 40 foot containers while identifying if containers are refrigerated or not. This provides a view on the breakdown of container physical types per commodity per port per direction per destination country.	Marine deep-sea, Transhipped, Empty
F6	Weight per container type	The average weight per container type can be deducted from the shipping line samples per commodity per port per direction per destination country per container type. This is an important parameter and parameter value used to translate containerised tonnes for each container physical type into the number of containers.	Marine deep-sea, Transhipped
R1	Disaggregated commodities adhere to related models	Introduced in Chapter 2. This is the inherent theme of this dissertation to disaggregate container content into a validated demand model. The detailed commodity descriptions from shipping line data help to inform and support the commodity disaggregation.	Marine deep-sea, Transhipped
A2	Port hinterland trade patterns	Introduced in Chapter 2, repeated in Chapter 3. Shipping line data provide specific trade patterns over several years for a combination of country, commodity, per port that can be utilised to enrich the economic input-output model. This should be made available to the FDM collaborating economists.	Marine deep-sea
A2	Port hinterland trade patterns	Introduced in Chapter 2, repeated in Chapter 3. Shipping line container content data provide a richness of trade partner historic data per commodity groups that can be used to inform port preference and trade partner preference. SARS data also provided insights into the extent of neighbouring country commodities traded through South African ports. This provides an input into the neighbouring country hinterland's decisions on using South African ports, or their own, or using transhipments via South African ports.	Transhipped
A7	Empty percentage	Introduced in Chapter 4. The TNPA container data provide a breakdown of empty containers as a percentage of full containers per port per direction. This is a level of granularity much higher and more specific than the global value. This value could be used in port planning for rough estimates, if a more accurate model for empty containers cannot be defined or is found too complex to execute.	Empty

Req. ID	Requirement	Motivation	Quay wall extent
A8	Transhipment percentage	Introduced in Chapter 4. The TNPA container data provide a breakdown of transhipment containers as a percentage of full containers per port per direction. This is a level of granularity much higher and more specific than the global value. This value could be used in port planning for rough estimates, if a more accurate model for transhipment containers cannot be defined or is found too complex to execute.	Transhipped
A13	Global physical container populations	Introduced in Chapter 4. The datasets showed signs of different container physical types, but more detailed input data would have been preferred to better inform this aspect of the model.	Marine deep-sea, Transhipped, Empty

5.7 Conclusion to industry dataset analysis

The industry datasets analysed provided inputs that enable the building of a more complex but also more accurate container model. Such a model would enable port planners to predict, plan for and implement infrastructure upgrades well in advance based on validated demand.

The datasets from the various parties, i.e. TNPA, SARS, TFR and the shipping lines were all instrumental in the understanding of the relevant parameters. Each of the datasets contributed in their own way to the development of the final set of parameters. These datasets would, however, be required for the continuous updating and improvement of the outputs, not only for the development.

To model accurately, correct values for each of the parameters would be required, i.e. the average weight of a specific commodity group that would go into a container type at a specific port exported to a specific destination. Starting values for the parameters can be determined from the industry datasets available and analysed in this chapter. However, the accuracy of these values needs to be improved through initiatives launched by port planners. One of the major reasons that port planners would need to launch further initiatives is due to constraints on the accessibility of data. Most of the required information is available on shipping documentation. Due to time and labour constraints the data is unfortunately not captured into an electronic database. If this data is available to the same or higher granularity continuously for years to come, the accuracy of the parameter values can be improved, and the outputs of the content-based model can be improved.

The datasets provided key knowledge on parameters and values especially for full quay wall containers for deep-sea shipments and to some extent also for transhipments and empty container movements.

A wealth of knowledge can be deduced from the shipping line data that could inform the developers of the economic input-output models. Aspects such as the volumes of commodities traded in containers between various international trade partners and the trends of these traded volumes over time can provide valuable inputs into a more accurate input-output model. Access to this input data would improve the overall accuracy of the FDM, the proposed container demand model and the complete surface freight modelling outputs.

A number of questions remain due to shortcomings identified in the analysis of some of the datasets. To get answers to these questions would require talking to industries that make decisions about container trade on a daily basis. Questions to be answered are:

- How are port choice decisions being made?
- How will weight per container type change in future and why?
- How far have commodities been containerised? Is there still room for further containerisation?
- What physical type container do they prefer and why?
- How do they decide which physical type to use?
- Where are their imported/exported containers unpacked/packed?
- Why at this location?
- What are the key drivers of modal choice (road/rail/coastwise)?
- What would facilitate a modal shift?
- Why are they using/not using coastal shipments?
- How do they source empty containers, and where?
- How much do they use transhipment, and why?

Further qualitative research would be the best option to answer these questions. The next chapter discusses the process for and the outcomes from the survey and focus groups that formed part of this research.

6. Qualitative research to enhance the industry dataset outcomes

6.1 Introduction

The previous chapter described the knowledge gained from the datasets that were provided by South African state-owned enterprises, shipping lines, industry and government bodies. This provided valuable inputs into understanding the parameters required for forecasting especially full deep-sea containers over the quay walls of South Africa. The shipping line data also provided valuable inputs into the current values to be used for these parameters in container modelling. More insight is needed into how these input values would change over the medium- to long-term forecast horizon. Some of the aspects of the forecasting model around domestic, transhipment, empty and coast wise containers cannot be defined precisely from these datasets. The future expectations around these aspects especially need to be better informed. To fill in this missing part of the picture, it was decided to collect primary data from industry. This was done through a survey and focus groups to obtain industry knowledge on the relevant aspects.

Inputs were obtained from industry through a survey and focus groups conducted by the researcher as part of a team. The researcher constructed and facilitated both these events and analysed the outcome. The first section of this chapter provides a picture of the methods followed. The second section of the chapter describes the outcomes of the survey and focus groups and how this informed modelling aspects of the different functional typologies. Feedback on survey and focus group questions will be given jointly per relevant topic.

6.2 Primary data collection design

6.2.1 Industry survey design

The industry surveys were a critical part of developing an accurate forecast for the types of containers which don't depend only on freight demand, but also on commercial and logistical factors. To obtain the input from freight owners, trade associations and industry, seven slightly different but targeted electronic questionnaires were developed as shown in Appendix D. Each survey was aimed at a part of the logistics supply chain and aimed at the following specific section: Associations and Organisations; Freight Owners; LSPs; Truck Companies; Shipping Lines; Port Terminal Operators; Inland Depots and Warehouses. The electronic survey links were distributed via email to the following recipients:

- Fifty associations and organisations were asked to distribute the survey among their members. The majority of freight owner responses received were as a result of this method.
- The eThekwini maritime cluster's list of maritime related businesses – approximately 350 businesses spread across all areas of the logistics supply chain.
- Four hundred trade-related businesses generated over two weeks from web sources and through cold calling businesses in the yellow pages.

In total, over 800 businesses were contacted directly. However, it is accepted that based on the methods used, up to half of these never actually reached the correct person due to outdated contact details on web sources. A week was spent making follow-up calls to ensure the emails had been received. The survey ran for a total of three weeks in April 2014. It is therefore assumed that at least, 400 emails (half) reached the correct person. Based on this assumption a response rate of 13% of all recipients was achieved, including those sent out by associations on our behalf. The distribution of responses received is shown in Table 6.1.

Table 6.1: Survey types and responses received per survey

Questionnaire Type	Responses Received
Associations and Organisations	2
Freight Owners	12
Logistics Service Providers	21
Truck Companies	7
Shipping Lines	8
Port Terminal Operators	0
Inland Depots and Warehouses	2
Total	**52**

Figure 6.1 shows a good spread of businesses along the supply chain, with some gaps being depots and port terminals. The majority of respondents were either freight forwarders (19%) or agents (18%), followed by freight owners and truck companies who make up 16% each. The remaining 31% of respondents were made up of shipping lines (12%), container trade and lease companies (7%), brokers (5%) warehousing and distribution (3%), and associations (1%).

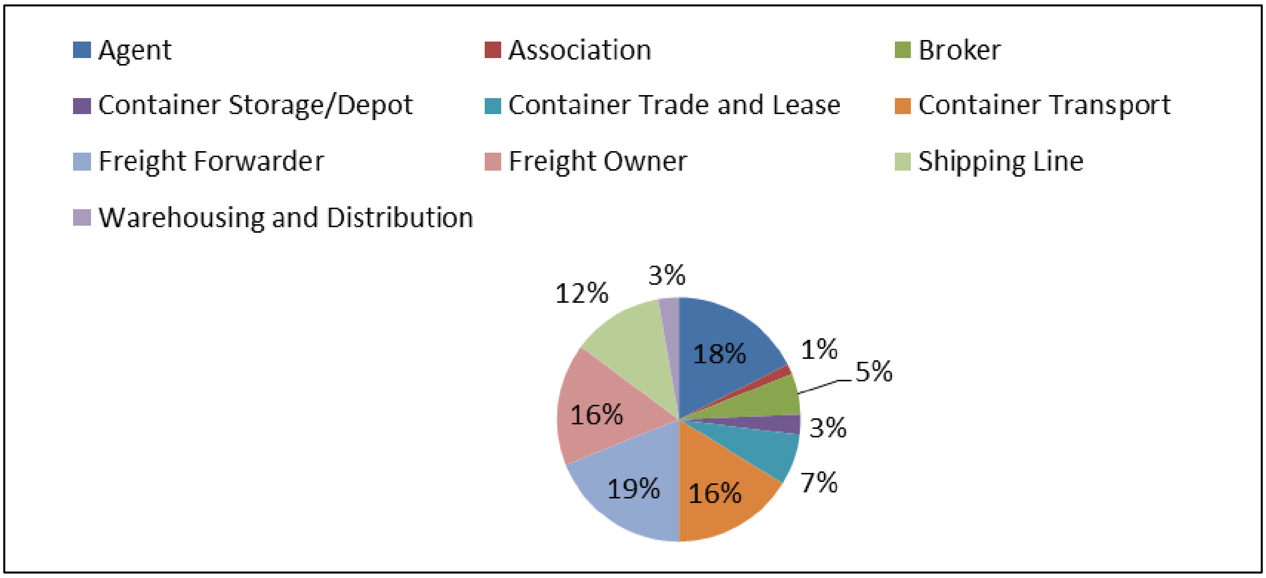

Figure 6.1: Nature of business of survey respondents

6.2.2 Focus group design

Two additional focus groups were held to fill the remaining knowledge gaps after the electronic surveys. Thus the focus groups were not per se a new design, but an extension of the survey questions to further enhance the answers and provide depth of understanding. This was done especially with regard to expanding the inputs to some key industry players who weren't captured in the round of e-surveys. The focus groups were about 2–3 hours each and included a 25–30 minute background presentation followed by discussion of specific posed questions on areas that needed more clarification. Two focus groups were organised in May 2014: one in Durban and one in Rosslyn, Pretoria.

Durban Focus group: The Durban focus group was held at the premises of the Durban Chamber of Commerce and Industry. The South African Association of Freight Forwarders suggested key players who were sent individual invitations and the Durban Business Chamber sent the invitation out to all their members. Hundreds of businesses were invited, 23 businesses were represented by mostly senior managers.

Rosslyn Focus group: The Automotive Industry Development Centre (AIDC) received a copy of the electronic survey and approached the project team due to interest from their area. Rosslyn is home to BMW and Nissan manufacturers, has a dedicated rail line and an MSC container depot. This opportunity was taken to arrange a focus group in this area, especially to understand the dynamics of logistics inland compared to the coast. Invitations were sent to a database of 270 businesses in Rosslyn and surrounds as provided by the AIDC. Fifteen businesses sent representatives from senior management to this focus group.

While all input was useful, the most important stakeholders accessed during focus groups are listed in Table 6.2. These companies represent most of the business types that the survey was also sent to. Although no specific truck companies or inland depots and warehouse participants were noted, many of the LSP's representatives also operate within these sections of the logistics network.

Table 6.2: A selection of the most notable stakeholders present at focus groups

Nature of Business	Some of the stakeholders present at focus groups
Associations and Organisations	South African Association of Freight Forwarders Perishables Products Export Control Board (PPECB)
Freight Owners	Toyota Nissan BMW Group Mondi Logistics Experts to the Textiles, Chemicals and Automotive clusters
Logistics Service Providers	Grindrod Intermodal transport solutions Bidfreight Intermodal Value Logistics M&S Shipping
Truck Companies	
Shipping Lines	Safmarine Shipping
Port Terminal Operators	Transnet Port Terminals
Inland Depots and Warehouses	

6.3 Outcomes from analysing qualitative datasets

6.3.1 Rate of containerisation

Survey respondents were asked to list factors that would impact on the containerisation percentage of specific commodities. Various relevant aspects were highlighted and detailed comments provided by the participants that further informed the marine deep-sea and coastwise typologies.

The major consideration according to respondents is the continued price difference between using containers and bulk. The container rate wars seen in the last couple of years led to continuing to containerise freight, especially, traditionally bulk goods such as steel and ferro-alloys. This was picked up in the shipping line dataset and lead to both an increased containerisation percentage of traditionally bulk commodities and an increased average weight per TEU for several ports.

Traders in chemical products base their decisions more on the benefits provided by the use of tanktainers vs large-scale bulk tanker ships. This reduces cargo handling and in the process improves security and reduces damage and loss. The nature of hazardous and food grade cargo means that it is also more suited to tanktainers than general bulk freight movements.

For perishable foods such as citrus, containers provide a secure option with more control from the freight owner's and customer's perspective and subsequently less damage to goods. Furthermore, more stringent protocol is being implemented at ports, requiring perishables to be moved in containers rather than reefer ships.

For the motor vehicle industry whose cargo is suited to various types of loading, the key is the speed of port offloading, port productivity and accuracy of estimated-time-of-arrival (ETA). If it is more effective to use bulk (roll-on roll-off) due to the speed of port handling then they will.

Focus group respondents confirmed these and also highlighted other aspects. One important aspect was the incentive to containerise food items due to risk of cross infection – e.g. citrus black spot. Purchasers will accept an unaffected part of a shipment if containerised, but not if in refrigerated bulk ships.

Focus group attendees also emphasised the freight rates as massively important when it comes to containerisation. Freight owners and participants in the supply chain need to forecast freight rates and do their planning based on this. At the time of the focus group it was cheaper to use containers, especially because at that stage the perception was that container capacity is ever-increasing. Despite this they emphasised that if this were to change, then many products would return to bulk.

The focus group attendee from Grindrod noted that they have to date not noticed anything against the trend with regard to the propensity to containerise. According to their opinion containerisation decisions depend heavily on freight rates, but also on infrastructure capacity and ability at the destination port, terminal and final customer location. This means that if a terminal/customer cannot load or offload a specific container or manage the freight in bulk, that will dictate the containerisation for the entire shipping leg.

Both the survey and the focus group outcomes confirm that the rate of containerisation is reaching a saturation level for most commodities. It also confirms that the erratic behaviour seen for some ports where some commodities are sometimes containerised and in other years not, can be ascribed to changes in destination infrastructure, short-term bulk capacity issues or container or bulk rate fluctuations driving these decisions.

6.3.2 Container weight

Survey respondents were asked a number of questions on the topic of weight per TEU. The outcomes further inform the functional typologies of deep-sea, coastal and domestic containers.

Figure 6.2 shows that almost three out of four respondents (73%) claimed their '*company have a drive towards greater volumes packed into each container*'. Of these 72% assigned this drive towards '*Cost/Economies of scale*' as being the major driver. Other drivers are: increased market share (16%); improvements in distribution chains (9%); reducing carbon footprint, and changes in manufacturing processes. The comment on increased market share relates to situations where a customer does not order a full container load, but less than a container load at a time. Unless consolidation of freight by various freight owners is possible, less than an optimum container load is often sent.

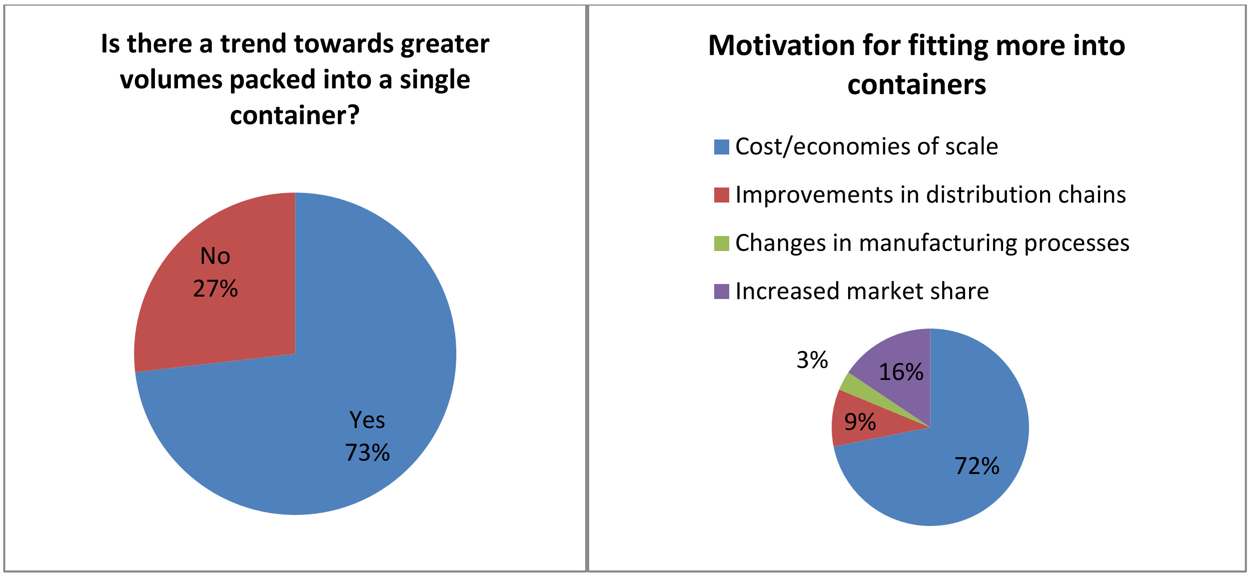

Figure 6.2: Trend towards fitting more products into a single container

On the question how companies '*aim to fit more into a single container*', the most frequent responses were: redesign packaging (44%); better stacking of products inside the container (25%); and increasing the size/type of container used (13%). This breakdown of industry feedback is shown in Figure 6.3. Other responses included utilising better loading equipment that would enable denser loading of containers, re-engineering the product itself, and also by increasing volumes to always ensure full container shipments.

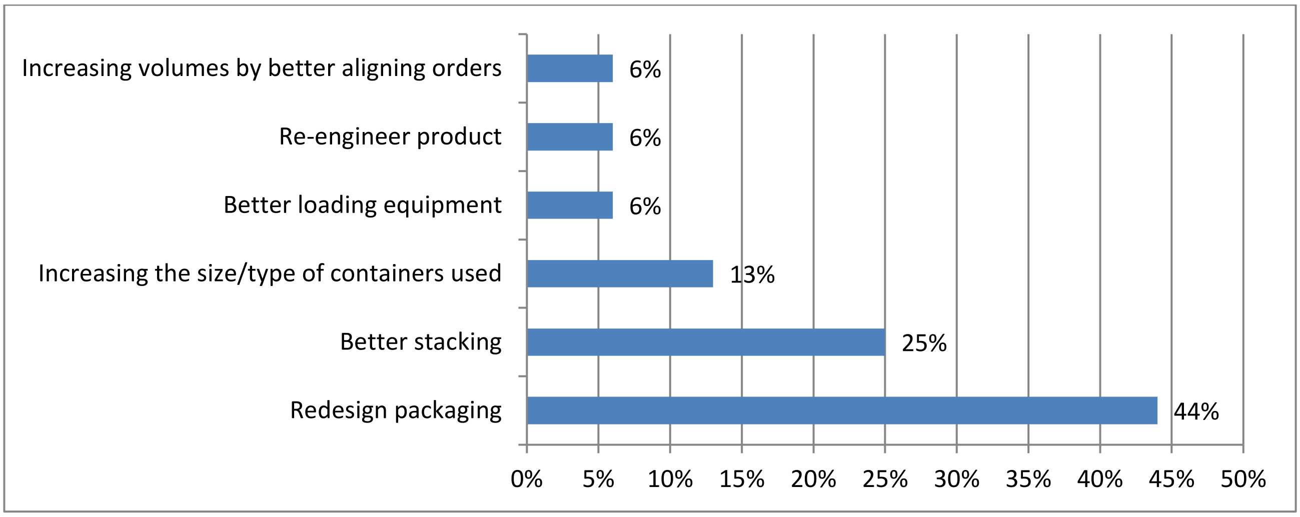

Figure 6.3: Company strategy to fit more products into a single container

The survey respondents were given the option to add comments to their decisions. Notable comments from the survey respondents were (copied as on survey):

- Redesign packaging to improve utilisation of space within packaging and the container.
- Product re-engineering, packaging re-engineering.
- Consolidating LCL cargoes/orders from the same region into FCLs. Trying to order maximum quantities to fill FCLs for imports.
- A greater need does exist to optimise loads.
- Packaging types have been improved e.g. cabbages packed into crates instead of bags allow stacking enabling us to pack more into a container.

- Lighter and more efficient packaging and pallets allows more products to be loaded per container and remain within container weight limits.
- Better packaging enables better and higher stacking
- Load more efficient packaging. Has effect on weight and therefore transport costs, etc.
- Better sizing of cartons, etc.
- Flexi Tanks are used instead of Drums and/or IBCs. It has positive impact on my business.
- Containers are now plate rated at 30 tons versus the previous standard of 24 tons.
- The high cube 40 foot container is becoming the standard over a normal 40 foot.
- Pack to maximum capacity, greater returns.

The impact of this phenomenon reaches much further than only the import and export of containers. It impacts all modes of transport, but especially shipping lines and road transporters that need to adhere to axle weight regulations. Shipping lines indicated that this will impact them in the following ways:

- In some cases ships were full on weight without utilising all the container slot capacity.
- Freight owners' container weight data is unreliable and often changes between the initial shipping documents being filed and when the final container arrives. This is a concern for ship stability and makes ship planning difficult. (Subsequent to this study and the survey, international container weight regulation was enforced to stop this behaviour.)
- Customers seek to achieve better cube utilisation, which can have weight, load implications and ship stability.
- Less weight per slot available.

This indicates that shipping lines will also have to plan their ship loading and offloading more carefully to utilise the capacity and ensure the stability of each ship when fully loaded. Ship design teams will have to consider this in capacity planning for future ships.

Road transporters responded that the impact would be that their trucks could take longer to unpack. Twenty foot containers might also change to high cube dimensions, and the number of trucks required to transport the same volume of freight might be reduced due to more being packed into each container, if the weight adheres to axle limitations.

The focus group participants mostly confirmed the above outcomes regarding changing container weights. Some notable additions and commentary during the focus groups were:

- Certain commodities, i.e. manganese, and other heavy mining minerals are too heavy for forty foot containers and have reached their maximum weight per container. These commodities will remain in twenty foot boxes or might even return to bulk shipment if bulk terminal capacity at the origin and destination ports is sufficient.
- Although many participants are trying to improve packing material further to squeeze out some transport efficiencies, many considered that they have already done what can be achieved.
- Another aspect from the focus groups is the road transport weight restrictions and road policy on movement of high cube containers. The trend to have heavier containers impacts the ability to use road transport for hinterland movement and hence increases the unpacking of imported containers and packing for exported containers at the port rather than at the freight destination or origin.
- One focus group participant highlighted that with their lightweight manufactured products they could only fit 4.255 tons into a 40 foot high cube container. This might be the case for many more products if South Africa would move towards increased beneficiation. If such strategies would materialise, special scenarios need to be considered with lighter manufactured sectors.

- Representatives from the automotive component manufacturers mentioned that for exported components their containers are often full for some components without reaching any weight restrictions, while in other scenarios they cannot utilise the space due to heavy components reaching weight limits with lots of space still available. Thus, the type of product does make a significant difference in container weight per TEU.

The conclusion and consensus from the survey and the focus group is that current data is sufficient to analyse the weight per twenty foot and forty foot containers, per commodity, per port for deep-sea and for coastwise shipments. The commodity trends experienced to date are expected to continue, within limits, over the next 5–10 years, then level off, or slow down considerably at least.

6.3.3 Packing and unpacking of containers

As described earlier, the packing and unpacking of containers at or close to ports has a significant impact on a number of functional typologies. Unpacking containers at port of import generates empty containers close to the port, while it stops hinterland movements of imported containers, and the subsequent availability of empty containers in the hinterland. On the other hand, packing of export containers at or close to the port, requires empty containers, and stimulates un-containerised movement of freight from the hinterland to the port region. This phenomenon impacts all the different functional typologies except transhipments. Many of the items discussed above influence aspects outside the scope of this dissertation; however, they do have an indirect impact on quay wall containers. A short discussion of outcomes is relevant.

In the survey, respondents were asked where containers are usually packed or unpacked. Full import containers travel to the point of unpacking where an empty container is generated. Therefore unpacking of import containers can occur at the port, near the port, at a warehouse or DC, or at the factory/premises of the freight owner. Understanding the location of where each container is packed and unpacked informs the extended modelling of both full and empty containers. A summary of the answer to this question is shown in Figure 6.4.

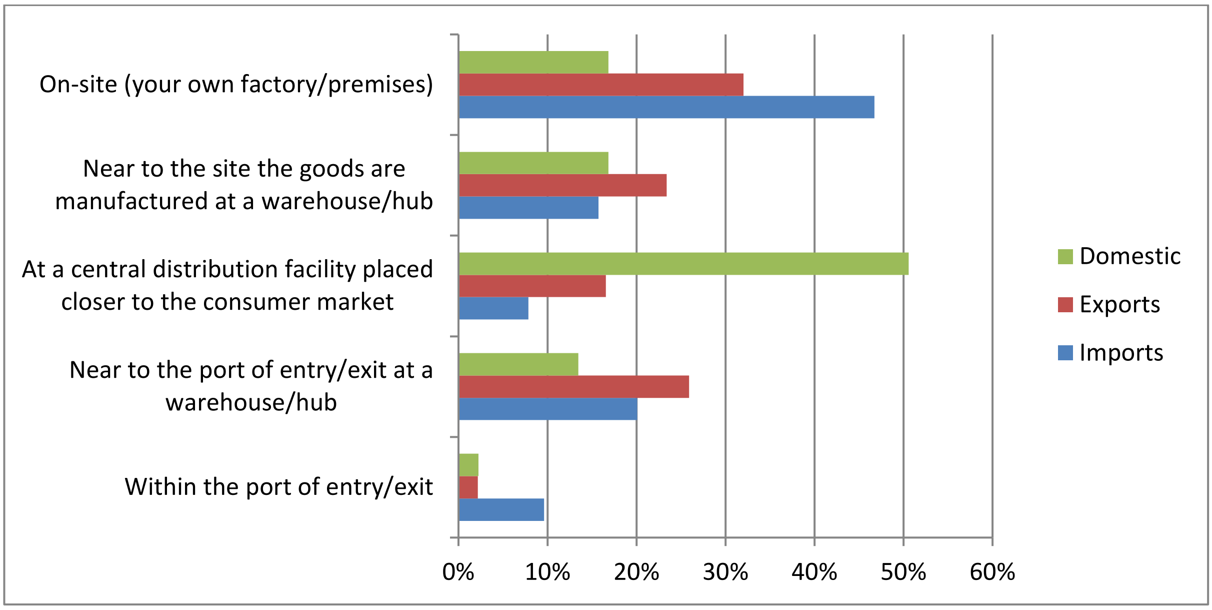

Figure 6.4: The location where containers are packed or unpacked.

Respondents importing containers indicated that 30% of import containers are unpacked inside (10%) or near to (20%) the port of entry. The remaining 70% of containers are unpacked at a DC close to the consumer (8%), or at a warehouse near to the factory (16%), or at the importer's factory/premises (47%).

For exports the numbers are slightly different. Respondents indicated that 28% of exported containers are packed inside (2%) or near (26%) to the port of entry. The remaining 72% of containers are packed at a DC close to the consumer (17%), at a warehouse near to the factory (23%), or at the importer's factory/premises (32%).

Domestic containers have a low market share, and a pattern of their own in this regard. Respondents indicated that 15% of domestic containers are packed or unpacked inside or near a domestic terminal. They also indicated that 51% of domestic containers are packed or unpacked at a DC closer to the consumer market. 34% of domestic containers are packed or unpacked at the factory or at a warehouse close to the manufacturing site.

This pattern is true for the respondents of the survey, but more investigation is required to understand whether this is a valid approximation for all South African ports, domestic terminals and commodity groupings. Further studies will be required to confirm specific values that need to be applied in especially the empty container modelling per port and domestic intermodal terminals, which falls outside the scope of this dissertation.

Survey respondents were also asked what drives their reasoning for packing and unpacking at the above locations they specified. A summary of the answers to this question is shown in Figure 6.5.

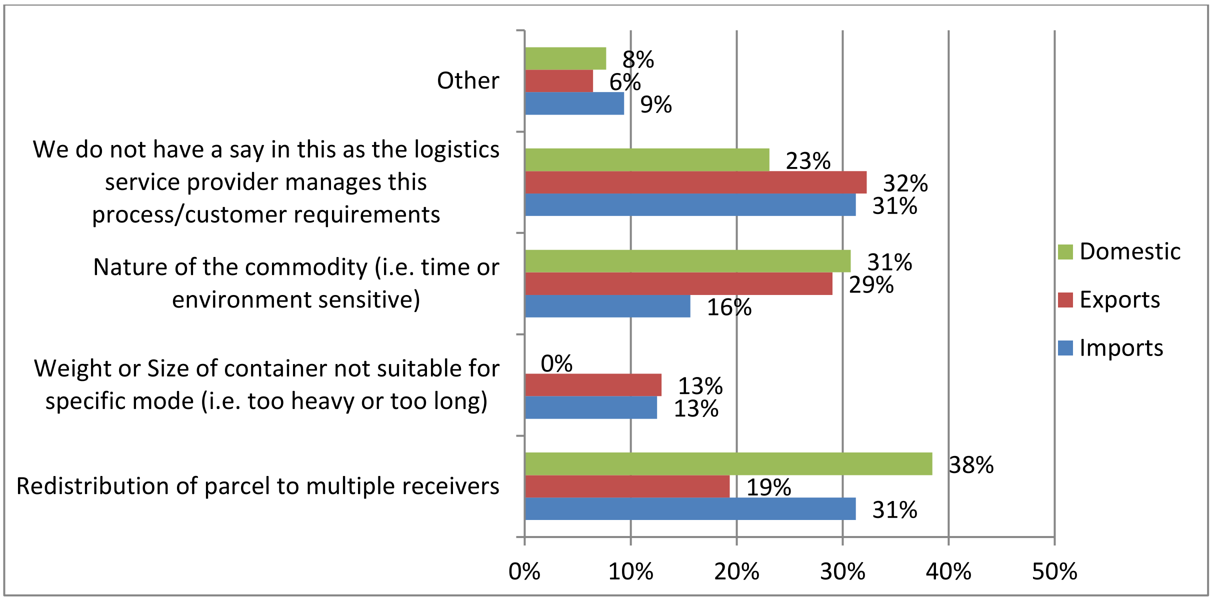

Figure 6.5: The reason for packing or unpacking containers at the specified locations

The major reasons why respondents unpack imported containers at the specified locations are due to preference from the customer, or logistics service provider (31%). Another reason is that parcels inside the container are destined for multiple receivers (31%) that could be in widely distributed destinations. Cross-docking of products from various containers is thus required before further domestic transport, and thus freight does not always end up back in containers for the domestic leg. Other reasons mentioned are the nature of the commodity (16%) and the container weight not being suitable for the preferred mode of transport (13%).

The major reasons why exported containers are packed at the specified locations are also due to preference from the customer, or logistics service provider (32%). For export containers the nature of the commodity (29%) is a big decision-making factor, and comments highlighted examples like fruit exports that are packed in reefer containers at the origin. Other reasons mentioned are that parcels inside the container are from multiple origins (19%) and consolidation at or close to the port is the sensible option. Respondents also indicated that some freight is packed at the port since it is not suitable for the preferred mode of road transport inside the containers (13%) from the origin, due to road weight or height limitations.

Domestic container decision-making considerations mentioned are the multiple origin and multiple receivers of the parcels inside a container (38%) and that decision is being made by the LSPs (23%). The reason for this behaviour was explained in the comment fields as LSPs that manage domestic freight for multiple freight owners use consolidation at their DCs with long-distance domestic container movements between their DCs. Another aspect that determines the location of packing and unpacking is the nature of the commodity (31%), determined often by specific loading or unloading equipment at the owner's facilities or due to refrigeration required for perishable items.

Survey respondents had the option to choose a category of 'Other' with open text answers available. Some of the items listed here were (quoted as provided):

- Need to pack and unpack on site;
- We have dedicated warehouse facilities for both export and import containers;
- Pricing, packing and distribution;
- JHB Turn in charge of the empty container;
- Wishes of the importer/exporter;
- Security at harbour is poor;
- Volumes.

Some of these responses could be incorporated with other answers, but the answers indicate very specific configurations in some supply chains that drive the decision-making. The configuration is usually done with a certain level of assumptions that were made in determining a cost-efficient solution for that supply chain, but maybe not for a cost-efficient solution across various supply chains, or for each individual shipment.

During the Durban and Rosslyn focus groups, participants were asked about the reasons for packing or unpacking at the port. Some participants indicated they prefer not to do this, but rather transport the goods in the container to or from their hinterland premises by rail or road. The primary driver remains the total cost of ownership, with key factors being: the cost of transport; the risk of damage or theft during unpacking; and the cost of the empty container relocation. Some of the automotive participants from Rosslyn highlighted that the risk of theft or damage when unpacking imported high-value components at the port are too high.

Some participants use rail for transport, but lead time and reliability of the rail service were deemed to be major challenges, especially in cases where frequency of shipments and sufficient volumes from one customer do not enable negotiations with TFR for block trains. The value of the items and the risk associated with unpacking high-value goods are also considerations. Many participants voiced that the risk of the cost in damages offsets the risk of increased transport cost sufficiently for them to move the container to the hinterland and pay the empty backhaul fee. Others stated the weight of the container itself being an issue which reduces their transport unit cost. Where road transport is preferred, more freight can be packed on the same road vehicle if not in containers, which often reduces the unit cost of hinterland transport.

The shipping line participants defended their policy that containers have to be returned to their depots for inspection before being reused. This policy is for protection of their containers and to reduce comebacks on issues with empty containers delivered not to standards of cleanliness and structural integrity. Some shipping lines do not have hinterland depots, meaning an empty container required in the hinterland needs to be moved to a coastal depot, inspected and then returned to the hinterland. Thus triangulation of containers is not allowed, which reduces the logistics efficiency on a macro level.

For export containers some unique cases were voiced. Perishable goods and high-value export items are two such examples. Freight owners prefer to pack perishable goods at their cold facility. This ensures the integrity of the cold chain through controlled inspection at the freight origin. Often labour is also cheaper at the rural origins of these agricultural products. This has an impact on the requirements for empty reefer containers in the hinterland. Owners of high-value export goods voiced the same principles of better control and risk management. Sealing an export container on their premises provides confidence that the goods arriving at the final destination would be what their clients ordered and that the condition of the goods will be in good order.

Some participants indicated that new DCs are often located closer to the coastal ports to reduce the hinterland movement of containers. Some have indicated that their companies had recently or are in process of planning relocation of DCs closer to the coastal ports.

The general feeling experienced from both survey respondents and focus group participants is that under current conditions the unpacking of containers close to the ports will continue and even increase slightly in percentage in the short to medium term. The survey and the focus groups merely scratched the surface on the whole issue of packing and unpacking of containers at or near the port, but opening that discussion further would require a completely different study with other objectives than this dissertation.

6.3.4 Container physical type

In section 2.1.1 nine container physical types were introduced that are used by port planners worldwide. This was introduced as a user requirement from Transnet port planners at that stage. A specific survey question was posed that asked: *'Do you foresee, or have your experienced your goods being transported in an alternative unit to containers, i.e. a new type of unitised storage?'* The vast majority of responses received were '*No*'. The explanation by those indicating 'Yes' to this question referred to reefer ships, tanker ships, and other bulk freight movements. No containers other than the ISO standard containers were mentioned.

Survey respondents were asked about the volumes of containers they handled for various physical typologies. A representative response on this question would enable the split of container movements into a wider variety of physical typologies. Shipping line data already provided a split between twenty and forty foot containers and an indication of reefer, dry or tanktainers. Participants provided the number of containers they used annually and the split between physical types. The weighted average container type split for the respondents is shown in Figure 6.6 for imported containers (sample of 108 000 TEUs, or 7.4%) and in Figure 6.7 for exported containers (sample of 128 000 TEUs, or 11.8%). This is not a representative sample, and thus not conclusive evidence, but merely an indication of the landscape for container types used in industry. The list of containers included in the survey was unfortunately also decided before the Transnet list defined in section 5.5.5 was finalised.

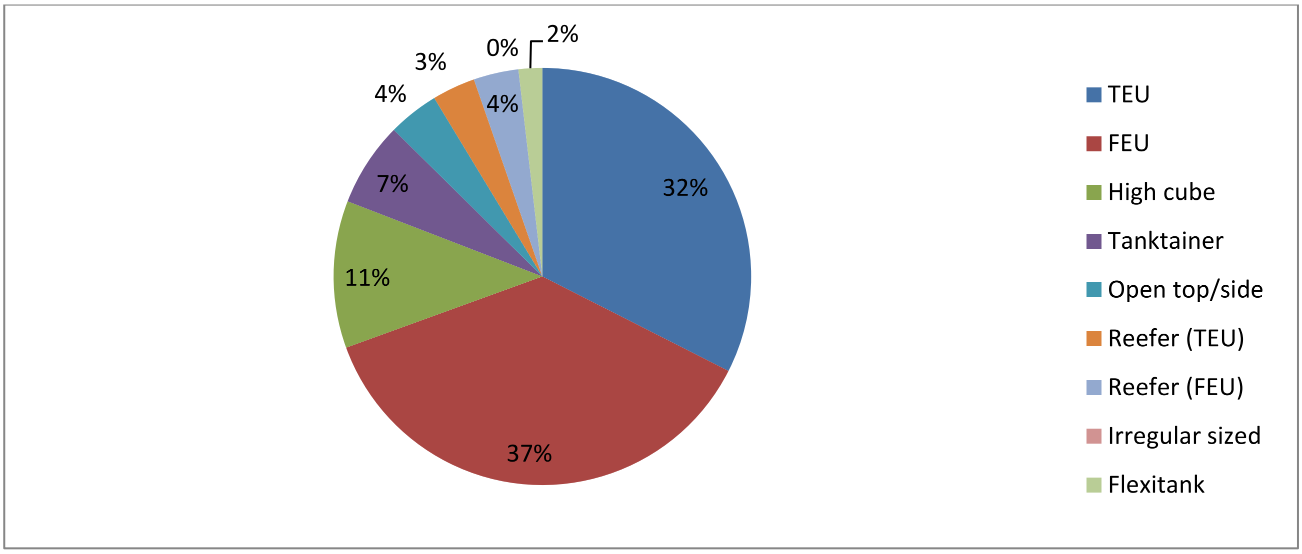

Figure 6.6: Respondents' view on physical typology of imported containers

The bulk of the import volume consists of standard twenty and forty foot containers, being either dry or reefer containers, with some of the respondents using high cube alternatives of these. Tanktainers also make up a considerable portion ascribed to imported chemical products considering the specific companies being part of the sample. A very limited number of other container types, i.e. irregular sized, open top/side and flexitank containers were used by the survey respondents.

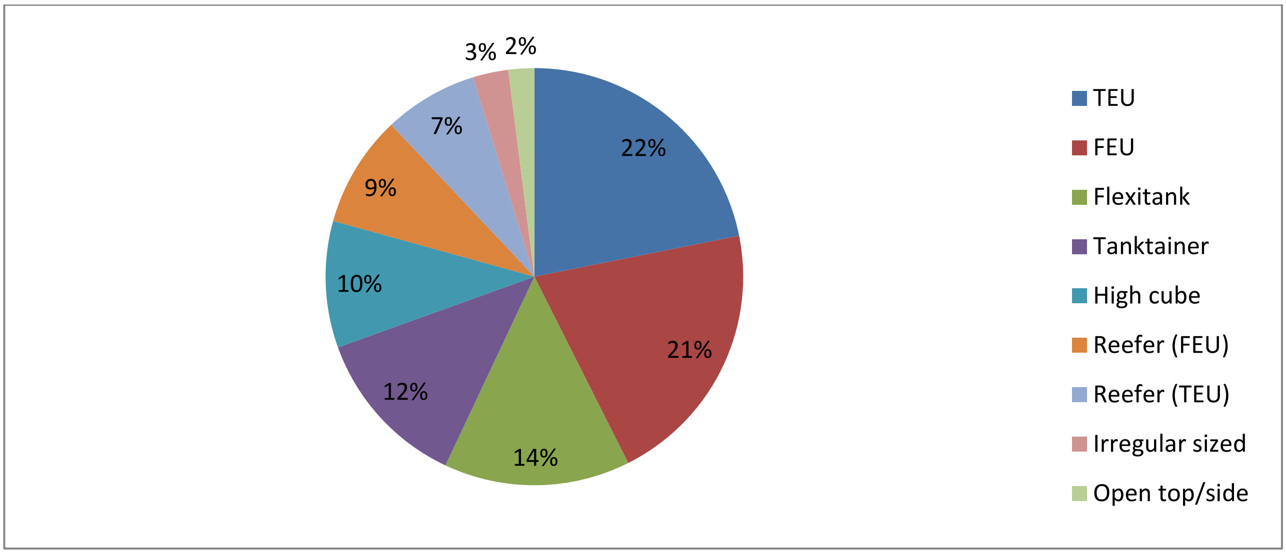

Figure 6.7: Respondents' view on physical typology of exported containers.

Survey respondents recorded a much wider range of container types for exported containers. Although open top and irregular sized containers are still small, tanktainers play a more prominent role in exports than imports. The survey asked respondents what the drivers are for the decision between twenty and forty foot containers. The responses received, saw that for international container movements the decision is linked to price (31%), nature of the commodity (27%), availability of the specific container stock required (19%), the parcel size (12%) and the availability of the particular slots on ships (7%). For domestic containers the major decision-making factor is the nature of the commodity (50%), then price (38%), and finally availability of the container stock (13%). A limited number of respondents feel that the shipping route, handling capability at the port, or the availability of slots on ships plays a role in their decision-making. The breakdown for both domestic and international are shown in Figure 6.8.

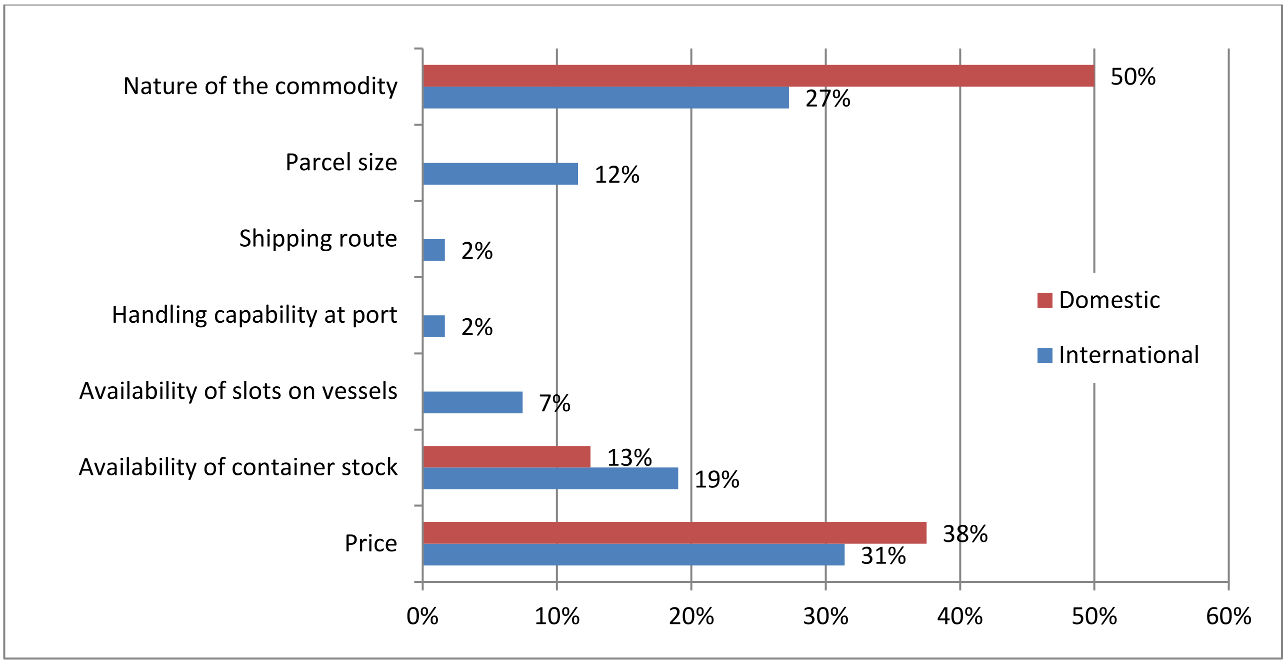

Figure 6.8: Respondents' view on decision-making factors between twenty and forty foot containers

Considering these factors it seems that many of the factors are not that easy to fix for a particular commodity and route in order to predict modelling variables. Factors such as availability of container stock and slots on ships are very much an operational decision that can change from week to week. Thus, there is potentially a level of strategic uncertainty due to this operational decision-making pattern that will have to be addressed in some way during the modelling process.

Similar graphs can be drawn for the decision-making factors involved for tanktainers and irregular-sized containers. At this stage the data received from respondents on these physical container types are not a representative sample and need to be further analysed in future research projects before final deductions can be made.

Some of the Durban focus group attendees were senior managers from a shipping line, the PPECB and other high volume container users. A couple of noteworthy comments regarding physical container types were received:

- Most forty foot containers are being manufactured globally.
- Most forty foot containers are being used on the larger volume northern hemisphere shipping routes (Europe/USA/Asia).
- The older twenty foot containers are being phased out and being directed to smaller routes, i.e. their physical condition is getting worse, and they are becoming less available.
- Globally the majority of forty foot containers manufactured are high cube.
- Perishable products are split 95% high cube forty foot containers and 5% twenty foot containers.
- The future container of choice was seen as the high cube forty foot container, with limitations to be considered being the destination port handling infrastructure and nature of the commodity.
- Discounts are given for importing non-refrigerated goods in switched off forty foot reefer containers into South Africa to facilitate the repositioning of these containers pre fruit harvest season.

Further analysis of the detailed responses by industry is required before this can be applied on a per commodity per port basis, and the limited sample size and diversity of commodities represented needs to be considered before the values can be applied to the modelling framework. The survey and focus group outcomes, however, confirm the relevance of the modelling parameters identified during section 5.4.6 from analysing the shipping line data.

The combination of trends seen in the literature review, trends seen in the shipping line data analysis and feedback from the survey and focus groups provide inputs that can be used to develop values for this shipping parameter. This can be done in broader groups called physical type families. This categorisation led to six physical type families that have a similar container physical type split and thus the same input values can be used for the base year. The six physical type families have been defined as:

- General Containerised (GC);
- Partly Refrigerated (PR);
- Refrigerated Only (RO);
- Refrigerated liquids (RL);
- Liquids only (LO);
- Liquids mixed (LM).

These physical family types are also expected to behave the same in terms of the composition of container types from here on forward. The logic is that each of the 83 commodities would fall into one of the physical type families and thus reduce the complexity of physical type behaviours that need to be understood. Figure 6.9 explains the database relationship where multiple commodities could belong to any one physical type family, and each physical type family could have a percentage allocation to multiple container physical types per base and forecast years. This adds some level of complexity in design, but reduces the level of complexity in determining values for each of the 83 commodities for all the physical container types. A number of examples are provided below to explain the concept further. Current available data from TNPA, shipping lines or any other source do not provide significant insight into this level of detail. It was therefore decided to group the physical types into six physical type families to provide for a lower modelling complexity than trying to be specific for all 83 commodities over all the forecast years. If subsequently higher levels of detail can be found, this can be used to improve the accuracy based on the physical type family configuration, or it can be removed.

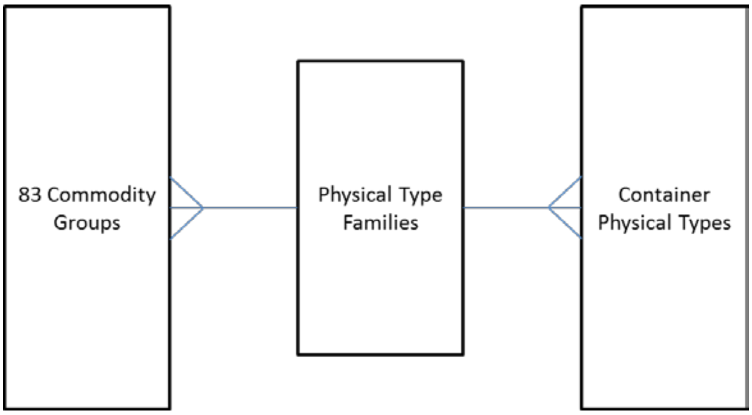

Figure 6.9: Relationship diagram between commodities, physical types and physical type families

Examples of families are containerised mining commodities of similar nature mostly in NTFUs, exported fruits in RFFUs, similar liquid bulk commodities in TANKs and lightweight manufactured commodity groups in HFFUs.

An example would be imported perishable items that are 100% refrigerated. This physical type family is called the *'Refrigerated Only'* family. Shipping line data indicate the base year values to be 45% RTFUs and 55% RFFUs. Literature reviews, the survey and focus groups provided an expected growth towards more forty foot containers, with two-thirds being the norm internationally for general purpose containers. No standards exist to accurately predict these values for reefer containers. An estimate used in this container model for the five-year forecast was 35% RTFUs and 65% RFFUs and for the 30-year forecast was 15% RTFUs and 85% RFFUs.

For exported containers in the *'Refrigerated Only'* physical type family, it started at a different base and is expected to grow very fast into forty foot containers as follows:

- Base year: 25% RTFUs and 75% RFFUs
- 5-year forecast: 15% RTFUs and 85% RFFUs
- 30-year forecast: 5% RTFUs and 95% RFFUs

The detailed assignment of commodities to physical type families and model values for all the families are shown in Appendix F. The accuracy of this section of the model is still to be improved. This might require an organisational process and database change at Transnet Port Terminals (TPT) starting to capture the container physical types and the related commodities as available on the current shipping documentation. This detailed information would provide more insight into current and future values for physical type families. The other alternative would be to do a large-scale industry survey to support the small survey done as part of this dissertation.

6.3.5 Growth of Africa as a big trading partner – road link via the Port of Durban

The economic foundation used in the container model should predict changes in economic trade, production and consumption. That would be true in an ideal forecasting world. The reality is that individual business decisions made by several businesses and new trade agreements made by governments can significantly change trade patterns between countries. The proposed container forecasting model does aim to translate economic activity into container demand. Thus, economic activity is at the core of this model and needs to be understood and used as the core of the input to the model.

Survey respondents were asked to provide insight into how their source and destination markets have changed over the past 10 years, and how they will change in the next 10 years. Thirty-five percent (35%) of respondents had changes in the last 10 years, and 34% see more changes coming in the next 10 years.

The related comments from respondents about source and destination market changes over the past 10 years can be grouped under the following headings:

- Trade in general: Some of the respondents have experienced a significant increase in world trade with South Africa. They also mentioned the impact of the weak South African currency on exports increasing and imports reducing in volumes.
- Changing partners: Respondents experienced many new trading partners with new suppliers and new exporters from these new markets.
- Far East: More imports from the Far East. Also more airfreight to and from the Far East.
- India and China: A shift was experienced from manufacturing in Europe to India and China.
- Australia: More trade with Australia was also experienced by many of the respondents.
- Near shoring: Some of the respondents also experienced that some of the manufacturing moving abroad and especially to the East is returning to South Africa.
- USA: The import volumes from the USA have reduced to very little.
- Africa: Export volumes have increased significantly into Africa over what they used to be.

These comments confirm the trends already seen in the shipping line container sample.

The related comments from respondents about the perception of their source and destination market changes over the next 10 years can be grouped under the following headings:

- Africa: Africa is seen as a new destination for exports and a growth focus of existing clients. West and East Africa are mentioned as a key focus by several respondents.
- Near shoring: Many respondents are seeing factories moving to different locations across the world, but also back to South Africa.
- Europe vs East. Respondents see Europe as major export partner to be replaced by the East.
- Changes will also be related to specific technology changes and related market leaders in these industries, e.g. solar from Japan.
- South America: Respondents also foresee new production facilities established in South America, with emphasis on Brazil as part of the BRICS community

Port capacity improvements and increased port efficiencies along the Southern parts of the East and West African coastline were described in section 4.4. This capacity expansion effect will make other transport routes to and from landlocked SADC countries viable. The volumes of SADC import and export freight through South African ports and along South African road and rail networks might be negatively impacted, which will reduce income for these service providers, but might also extend the lifetime of existing infrastructure before capacity upgrades are required.

6.3.6 Seasonal demand

Respondents experienced that in their industries about half of all internationally traded containers are distributed unevenly throughout the year. This is mostly due to 1) products or industries being seasonal, and 2) product demand in the industry fluctuating throughout the year. Fluctuating demand due to agricultural seasons (fruit specific), holiday seasons (Dec–Jan), plant shutdowns (Dec–Jan), customer demand (various), bulk buying (various), strikes (various) cannot be predicted in a long-term focused model of this nature. However, these seasonal patterns have a very specific and known impact on various container-related movements. The requirement for empty containers, and specific physical types, i.e. reefers for export during the agricultural seasons are especially high. Also Christmas and school holiday seasons around December and January in South Africa have an increased import cycle of containers leading up to this time period every year.

Some insight has been provided by respondents, but further analysis is required to obtain a reliable answer on predicting this. The extent of accuracy is not critical for this, given the long-term focused nature of this dissertation.

6.3.7 Empty container repositioning

At the point of unpacking of goods from a container, an empty container is generated. Similarly at the point of packing of a container, an empty container is required. The key to the modelling of empty containers is in understanding the packing and unpacking locations of full containers. This phenomenon has to some extent been explained in section 6.3.3. Further research is required to clearly understand this and to make accurate predictions on the movement of empty containers. However, some insight has been provided through the survey and focus groups.

The other aspect that adds to the complexity of the empty container modelling exercise is that it is in fact an operational level decision made on a daily basis. However, the modelling needs to be done on a longer time frame and daily/weekly/seasonality imbalances thus cannot be considered. For long term modelling purposes annual imbalances between supply and demand for empty containers can be utilised due to the availability of this level of data. The short-term operational repositioning of empty containers cannot be modelled within a long-term national framework. Other short-term focused models need to be developed to solve these issues. Manufacturing of new containers and scrapping of old broken ones should also be considered. The latter is of more significance in the South African context due to the current import/export imbalance.

Figure 6.10 shows the breakdown of where freight owners and LSPs source empty containers from.

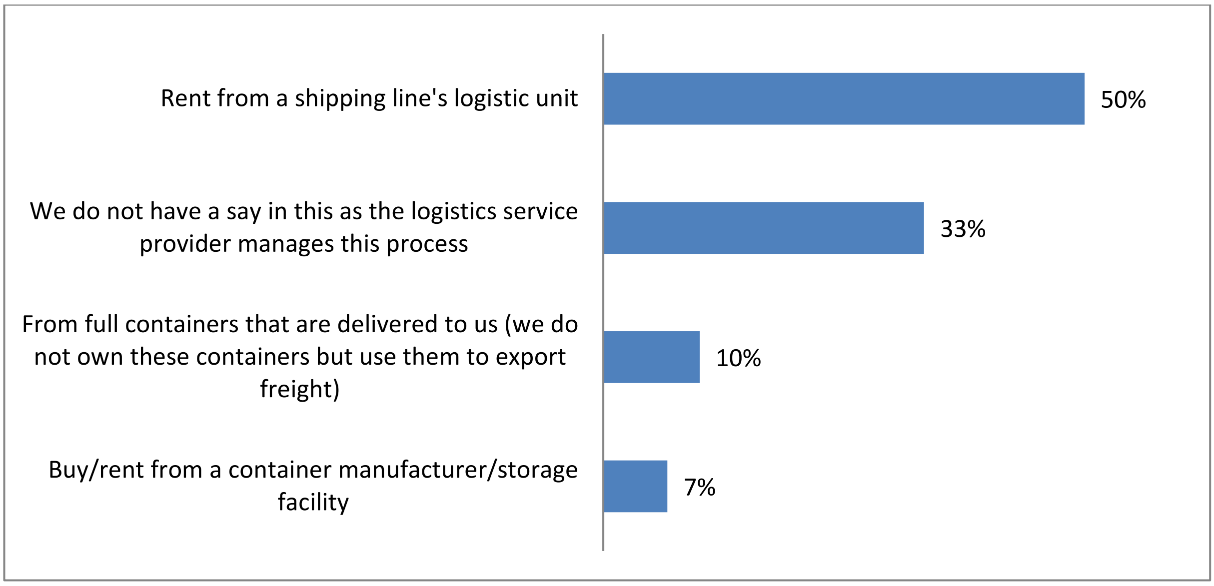

Figure 6.10: Where empty containers are sourced from

The survey respondents indicated that 50% of all containers were rented from a shipping line's logistics unit close by their facility. A third indicated that they cannot determine this, since the LSPs make this decision for them. One out of ten obtain their empty containers from unpacking full containers on their own premises, and 7% buy or rent an empty container directly from either a container manufacturer or container storage facility. It is clear from this that the shipping lines and LSPs control the movement and availability of empty containers and that freight owners need to accept what is enforced upon them.

Focus group attendees' related comments were:

- Perishables are mostly packed into containers at origin. This leads to a high requirement for empty reefers being moved to these origins, often rural areas.
- Shipping lines are returning reefer containers in pre-harvest season to South Africa with incentives for dry cargo (non-contamination) owners at a 15–20% reduced fee with less cargo inside (due to space taken by refrigeration unit).
- Shipping lines charge an empty return fee if an imported container is handed back at a hinterland depot and not at the port. This fee ranged between R4 000 and R5 000 in 2014.
- The lack of exported manufacturing goods leads to a significant container imbalance in South Africa. This lead to the Port of Durban 'exporting' in excess of 430 000 empty containers in 2013. An increased focus on beneficiation (industrial manufacturing) would benefit the imbalance, and affect the empty container model.

Many of these are valuable arguments that need to be considered for empty container modelling. This discussion will be continued in Chapter 8.

6.3.8 Container Transhipment

The survey attempted to understand the factors that cause container transhipments. Figure 6.11 shows the factors highlighted by respondents.

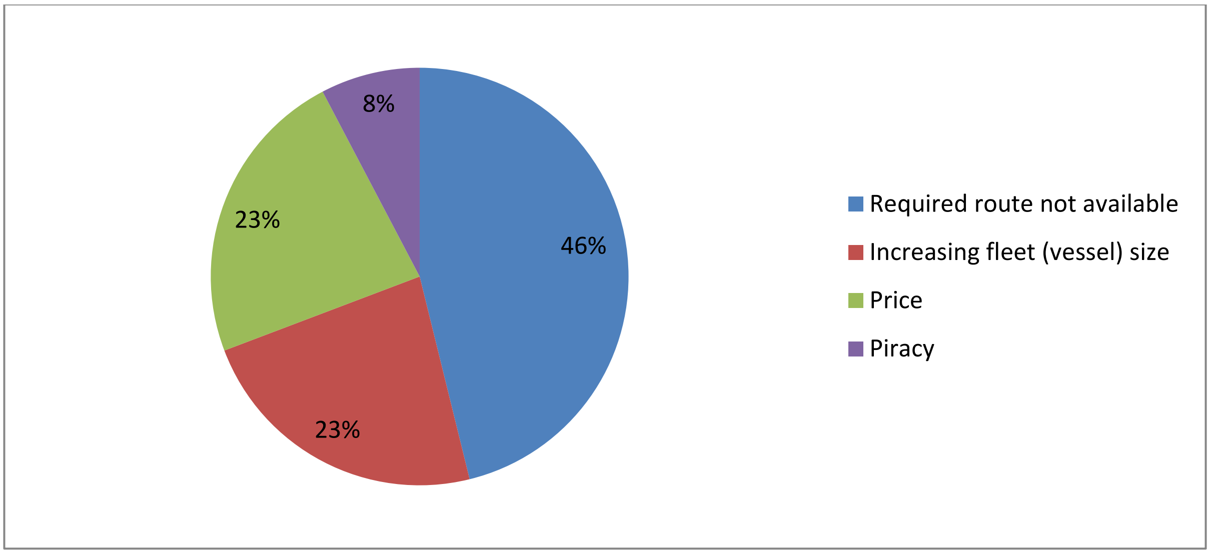

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Figure 6.11: Factors that cause the transhipment of containers

The majority of respondents (46%) indicated that transhipments of their containerised goods are caused by the required direct route not being available. Other factors that influence this are the increasing size of ships (23%), the price involved in shipping directly (23%) and piracy (8%). Other factors mentioned by the respondents were shipping lines providing flexibility to accommodate their clients, shipping lines choosing this option to saving on ship-related costs, and thus redefining shipping networks and ship size to operate their overall international services on time and as cheaply as possible across various routes to multiple clients. Thus, it can be concluded that this is merely a function of economies of scale on a shipping line level within the current given trade volumes per route.

Respondents were asked what the drivers of transhipment activities at specific South African ports were. The responses received can be categorised per port as follows:

- Port of Durban:
    - Transhipments in South Africa are avoided where possible due to high costs and lack of reliability of berthing.
    - Despite this, transhipment is done at the Port of Durban for routes between South America and India–Middle East, also connecting the Middle East and India to East Africa and the Indian ocean.
    - The Port of Durban is utilised for Mozambique imports/exports that are relayed to and from Maputo port.
    - Restrictions of transhipments are due to space limitation, price, and port congestion amid current refurbishment projects.
- Ports of Ngqura and PE:
    - Transhipment is done at these ports linking routes of South America to India and Middle East; Brazil via South Africa to the Middle East; and also transhipments from and to various origins and destinations to West and East Africa.
    - Maintaining Deep-sea Schedule Integrity.

- Port of Cape Town:
    - Transhipment is done at this port linking routes of West Africa to India and the Middle East, Angola and Namibia.
    - Cape Town gets preference due to Namibia's demand, and space limitations.
    - Maintaining Deep-sea Schedule integrity.

Major drivers in the shipping line decision-making about direct route vs transhipment are the efficiency of their shipping fleet, transit times they can promise to customers, freight cost and volumes. Shipping line's economies of scale is determined by the volume of freight that can be shipped on a route with the ship size chosen, the ability of ports to receive the ship size required, the port efficiencies and port turnaround times. As ship sizes increase, the deeper the calling ports should be, and the higher the container-handling capacity is required to ensure a quick ship turnaround. The more freight a ship can move in a year, the more income it can generate. Transhipments add to lead time as the route is usually a longer distance and dwell time in the transhipped port can be a couple of days and attract extra port handling fees.

6.4 Design requirements identified in this chapter

This chapter addressed a wide range of events and inputs from numerous different players in the transport and trade business in South African industry. The initial focus and objective was to confirm existing knowledge obtained through the industry datasets analysed in Chapter 5. The major output from this research process was planned to be twofold: to confirm the importance of earlier parameters identified and to obtain knowledge on the influencing factors that will change the values of these parameters in the short to medium term (5–10 years). The overview of the model design requirements as defined and confirmed in this chapter are shown in Table 6.3.

Table 6.3: Design requirements identified in Chapter 6 (numbering continued from Table 5.4)

Req. ID	Requirement	Motivation	Quay wall extent
F2	Percentage containerisation	Introduced in Chapter 2, repeated in Chapters 3, 4 and 5. Survey respondents and focus group attendants agreed that palletisable commodities will continue to gravitate towards containerisation, striving towards 100%. Especially high-value commodities. They however felt that many of these commodities are approaching their ceiling values of containerisation which might for some commodities be less than 100%.	Marine deep-sea
F6	Weight per container type	Introduced in Chapter 5. The weight limit and weight reporting restriction was noted, and the drive to pack more items into containers was emphasised. Many commodities have achieved their limits though, and continued aggregated trends up or down are regarded as shifts in the composition of the commodity content, i.e. different commodity groups being traded in containers.	Marine deep-sea

Req. ID	Requirement	Motivation	Quay wall extent
U3	Container unpack position and transport modes	Introduced in Chapter 2. Although this should be seen as a functional requirement for surface freight modelling, it is an extension of containerised freight that crosses the quay wall. Although this is an aspect that has reference to this model, it will be deemed outside the scope of this dissertation. The valuable inputs received during the qualitative research data collection and analysis were relayed to modellers that could utilise these inputs in their models.	(Out of Scope: Domestic intermodal)
F5	Container physical types	Introduced in Chapter 2, repeated in Chapters 4 and 5. The qualitative research confirmed various values and trends from Chapters 4 and 5, but also emphasised moving towards using more 40 foot containers where weight limits and the nature of the commodity allows it.	Marine deep-sea, Transhipped, Empty
A2	Port hinterland trade patterns	Introduced in Chapter 3, repeated in Chapters 4 and 5. Confirmation of business expansion to several African countries with exports via ports growing in potential vs border post and cross-country as preferred option.	Marine deep-sea, Transhipped
A13	Global physical container populations	Introduced in Chapter 4, repeated in Chapter 5. Survey respondents and focus group participants highlighted the changing patterns in world physical types towards 40 foot containers. Their own preference is more towards 40 foot containers where facilities along the routes can accept them.	Marine deep-sea, Transhipped, Empty
A14	Container unpack position and transport modes	Introduced in Chapter 2 (as U3) and repeated earlier in this table. Feedback was provided on the reasons for specific packing and unpacking decisions on place and the preferred domestic transport modes to and from the port. The packing and unpacking position of full quay wall containers has reference to the destination and origin of empty containers respectively. Thus this information would be beneficial to the domestic intermodal and empty models.	Empty
A15	Container transhipment factors	Feedback was provided on the factors that dictate quay wall containers to be transhipped at international ports. This provided insight into why international freight is being transhipped at South African ports. The packing and unpacking position of full quay wall containers has reference to the destination and origin of empty containers respectively. Thus this information would be beneficial to the transhipment model.	Transhipped

6.5 Conclusion

This chapter provided an overview of the research conducted with freight owners, industry associations, LSP, shipping companies, port authorities and terminal operators. Their inputs furthered the understanding of certain parameters, their current input values and how the input values will be influenced in the medium to long term.

The analysis provides confirmation on the importance of including container content into quay wall container forecasting and planning. Various decision aspects were discussed: to containerise or not; increasing weights per container; the packing and unpacking position of containers; container physical type preferences, empty container sourcing, modal choice for domestic transport, etc.

The feedback from survey respondents and focus groups confirmed the user requirements identified prior to the survey and the focus group events. It also confirmed the importance of the identified requirements and the inputs that were obtained from analysing the container content data obtained from shipping lines.

The following chapter will consolidate all of the inputs generated in this dissertation into quay wall container model requirements for South Africa. These model requirements will focus on:

- Marine deep-sea full containers

It will also provide some insights into more complex alternative models that were listed as secondary objectives of this dissertation:

- Marine transhipment containers
- Marine empty containers

Many of these outcomes were gained from the research approach and the contacts with industry and might as well be shown as fringe benefits and inputs for future research projects. Due to completeness in this research project they need to be considered, but the results deemed them not relevant to quay wall container demand.

7. Consolidating the identified design requirements

7.1 Introduction

Several requirements as defined by Van Aken et al (2006) have been deducted from aspects covered in Chapters 2, 3, 4, 5 and 6. Chapter 2 referred especially to user requirements as dictated by the integrated nature of the container demand model design with the FDM and other related surface freight models. Chapter 3 analysed literature on container modelling techniques to establish further design requirements. Chapter 4 focused on the supply- and demand-side factors in the container industry and the impact these aspects would have on a proposed content-based container modelling framework. Chapters 5 and 6 discussed and analysed design requirement inputs from industry datasets, a survey and focus groups.

This chapter utilises these discussions and analysis outputs to consolidate container modelling elements: i.e. inputs, parameters, and forecasting influencers that all culminate in the container modelling development process in Chapter 8 following from here. This would generate outputs for each of the functional typologies defined in section 2.1.3 deemed in scope. The container model will be developed in separate sections per functional typology to fulfil the stated research objectives:

- Primary Objective: Marine Full (Deep-sea)
- Secondary Objectives: Transhipments (Natural and Targeted)
- Secondary Objectives: Empty repositioning (Marine)

Just to refresh the reader again on the extent of these functional typologies, Figure 7.1 repeats some of the typologies that were discussed in section 2.1.3. (This is an adaption of Figure 2.1 for convenience.)

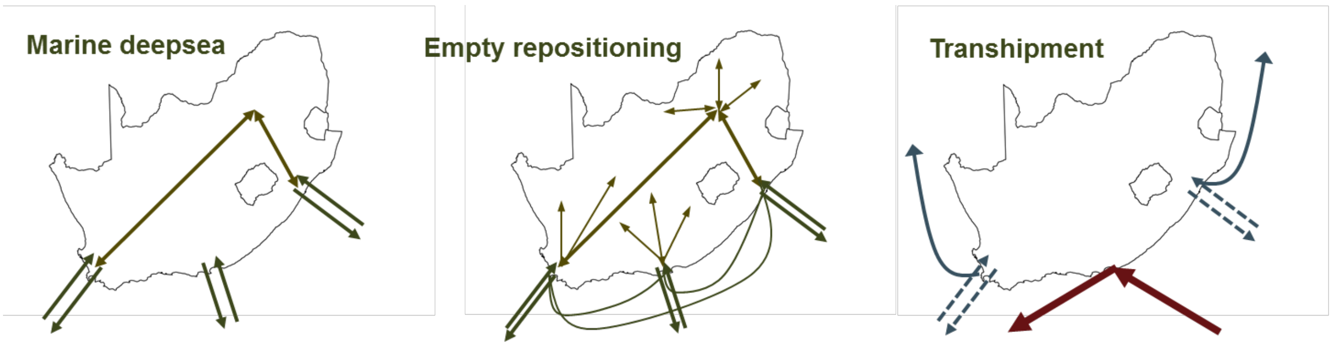


Figure 7.1: Functional typologies explained graphically in the South African context

7.2 Consolidated design requirements

As a refresher to the reader, the definitions of design requirements derived in section 1.8 from Van Aken et al (2006) are repeated. These definitions have, for the purposes of this study and the mixed-methods research design followed, informed the requirements through detailed data collection and analysis in search of these aspects as follows:

1. User requirements (U): Specific requirements from the view of the user of the forecast model will determine the required outputs of the model. This pertains specifically to port infrastructure planners (Model Outputs);

2. Functional requirements (F): The functional requirements of the container forecast model impacted by an analysis of the quantitative and qualitative datasets and informed by literature on existing container modelling techniques to establish the key input parameters of the model (Parameters);

3. Design restrictions (R): The non-negotiable input requirements for a viable container forecast model. The proposed container model needs to interact with other surface freight forecasting models to obtain inputs and in providing inputs for other models. Thus it needs to adhere to design restrictions dictated by related models. (Inputs);

4. Attention points (A) and Boundary conditions (B): Trends in the local and global demand and supply landscape that will act as broad influencers on the container forecast model (Influencers).

These design requirements have been combined and consolidated as shown in Table 7.1. The table provides the following detail columns:

- Unique *Requirement ID* (carried through the dissertation);
- *Requirement description*;
- The chapter(s) where the requirements was identified for inclusion; and
- *The Functional typology* that the model requirements apply to.

These design requirements are briefly discussed below the table as each of them relates to the three quay wall functional typologies identified above: Marine deep-sea full containers, Transhipment containers and Empty containers.

Table 7.1: Consolidated design requirements

Req. ID	Model requirement	Chapter identified					Applicable to Functional Typology		
		2	3	4	5	6	Marine Deep-sea	Transhipment	Empty
User requirements: (Outputs)									
U1	Disaggregated commodities	X					X		
U2	Container physical types	X					X	X	X
U3	Container unpack position and transport modes (*This requirement is applicable to a surface freight intermodal model, and thus out of scope)	X				X			
Design restrictions: (Inputs)									
R1	Disaggregated commodities adhere to related models	X			X		X		
R2	Parameters applied to origin-destination data	X					X		
R3	Forecast year breakdown	X					X	X	X
Functional requirements: (Parameters)									
F1	Spatial disaggregation	X					X	X	X
F2	Percentage containerisation	X	X	X	X	X	X		
F3	Disaggregated commodities	X	X				X		
F4	Port preference		X				X		
F5	Container physical types	X		X	X	X	X		
F6	Weight per container type				X	X	X		

Req. ID	Model requirement	Chapter identified					Applicable to Functional Typology		
		2	3	4	5	6	Marine Deep-sea	Transhipment	Empty
Attention Points: (Influencers)									
A1	Only palletisable freight should be in containers	X					X		
A2	Port hinterland trade patterns	X	X	X	X	X	X	X	
A3	Hinterland economic structure		X	X			X	X	
A4	Port competitive position		X				X	X	
A5	Hinterland states: Investments		X					X	
A6	Port hinterland integration		X					X	
A7	Empty percentage			X	X				X
A8	Transhipment percentage			X	X			X	
A9	Port capacity and efficiency			X			X	X	X
A10	Container ship size			X			X	X	X
A11	Shipping line route decisions			X				X	
A12	Global shipping fleet			X			X	X	
A13	Global physical container populations			X	X	X	X	X	X
A14	Container unpack position and transport modes					X			X
A15	Container transhipment factors					X		X	
Boundary conditions: (Influencers)									
B1	Weight limits enforced per container physical type	X					X	X	
B2	Funding limitations		X				X	X	X
B3	Port regulation and ownership		X				X	X	X

The users were adamant that a user requirement for packing and unpacking of deep-sea marine containers should be included. This user requirement of containers being unpacked in specific positions and utilising certain transport modes (U3) relates to a domestic intermodal modelling framework. This is outside the scope of this dissertation and the relevant information obtained through the primary research has merely been passed on to other interested parties. Although this user requirement might be applicable to many of the remaining design requirements, it will not be included in the continuing discussion.

The modelling framework for the marine deep-sea functional typology should adhere to the specific user requirements pertaining to disaggregated commodities (U1) and container physical types (U2). The user requirement for understanding container physical types (U2) is important for all three of the in-scope functional typologies informing future quay wall infrastructure requirements.

The design restrictions identified for the marine deep-sea modelling framework relates to using the same commodity breakdown (R1) and the parameters chosen should be able to be applied to existing modelling data (R2) as related models use these as input values. Another design restriction identified for all three typologies relates to using the same forecasting year frequencies and intervals (R3) to coordinate and integrate easily with related models.

The first functional requirement identified, relating to spatial disaggregation (F1) is relevant to all three functional typologies included in the scope. The other five functional requirements are applicable to only the marine deep-sea model, i.e. the primary objective of this dissertation and thus the 'heart' of the model that is to be developed in Chapter 8. These functional requirements relate to the commodity groups (F3); the percentage of each of these that are containerised (F2); the preferred port of import or export (F4); the container physical type (F5) that freight owners would chose; and the weight they would be able to pack into each container (F6).

Many of the attention points identified in the research are applicable to all three of the functional typologies. Examples are aspects related to port capacity and efficiency (A9), container ship size (A10) and container physical types (A13). Two of the attention points were found to relate to only the Empty container typology, i.e. historic trends for empty containers per port (A7) and the container unpack position as starting point for empty containers (A14). Similarly, many of the attention points related to transhipments only. Key aspects that need to be monitored for future influences on the transhipment typology are the port and hinterland investments made by hinterland states (A5) combined with the level of port hinterland integration (A6) experienced and how this would influence the shipping line route decisions (A11) to incorporate additional competitive ports into their routes. Added to this typology would be the historic transhipment percentage per port (A8) similar to the historic value for empty containers and the container transhipment factors (A15) identified in Chapter 6 from feedback by focus group participants.

Several attention points can be linked to both the marine deep-sea and transhipment typologies since both are full containers linked to hinterland related criteria. Some of these are port hinterland trade patterns (A2), the hinterland economic structure (A3), and port competitive position (A4), while the global shipping fleet (A12) will also impact the volumes of full containers being shipped and transhipped through South African ports. Of all the attention points, only one is only related to marine deep-sea full containers, i.e. those commodities deemed palletisable should be in containers (A1) and other commodities should be catered for with other infrastructure like bulk terminals.

Three boundary conditions have been identified, which relate to all three functional typologies except for the weight limits (B1) aspect that does not apply to the empty container typology. The other two boundary conditions are funding limitations (B2) that has a wide effect on South African and competitive ports throughout the sub-Saharan Africa region, and port regulation and ownership (B3) aspects relating to South African ports.

The interaction between the supply of and demand for containers is described in Figure 7.2 showing the two sides impacting the container movements. On the one side is the demand for freight transport where freight owners require moving a specific commodity from the origin to the destination of the customer. Based on the traded product's characteristics a decision would be made to containerise the freight or not, which creates a demand for containers.

Various supply chain considerations (i.e. cost, supply chain objectives, transport inventory trade-offs) would be included in the decision on how frequent and in what volumes the product would be shipped to the customer. This leads to a number of loaded containers, their weight and how full they would be. At the centre of the demand side is the detailed understanding of the content of containers. This side of the diagram provided most of the design restrictions and functional requirements to the container model requirements listed above.

On the other side would be the supply of freight transport capability including specialised equipment such as ports, terminals with container-handling equipment as well as container ships, and road and rail transport infrastructure. This leads to the supply of container-enabled infrastructure that provides input for infrastructure operators to create shipping networks and intermodal collaboration with the ability to transport a variety of container types, leading to the supply of container transport ability. This side is mostly addressed through attention points and boundary conditions.

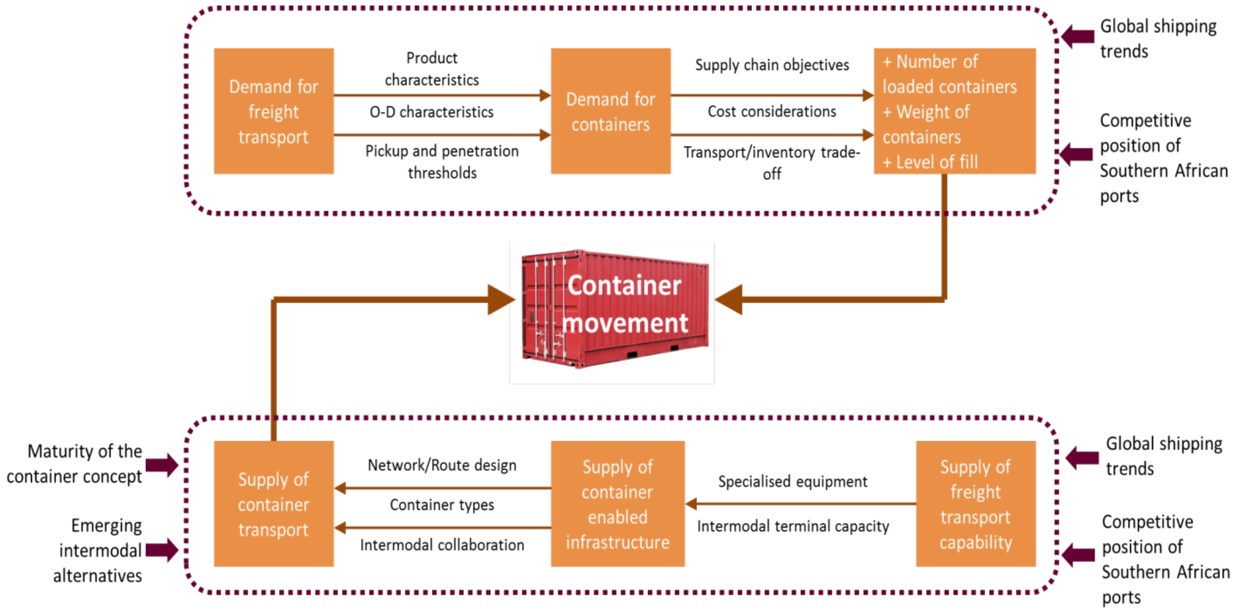


Figure 7.2: Demand and supply side modifiers of container transport

7.3 Conclusion

Commodity groups are at the core of the content-based approach. It is crucial to clearly identify these groups in an inclusive way to serve the purposes of all participants as was explained in section 2.2.

The key functional requirements, called parameters in the full quay wall container model, have been identified and parameter values obtained through data analysis. These key parameters to forecast container volumes moved across the quay wall, are:

- Spatial disaggregation to define outputs per international geographic region and per port;
- Rate of containerisation of each commodity;
- Commodity port preference;
- Physical container types;
- Weight of commodity per physical container type.

The user requirements and design restrictions are guidelines that would determine the specific inputs and outputs to ensure that the model integrates completely and seamlessly with the other surface freight forecast models for container and bulk freight mentioned earlier in section 2.1.4.

Several attention points and border conditions were identified that will influence the parameter values over the next five to ten years. These will need to be monitored and better understood to apply a process of continuous improvement in the modelling accuracy.

The next chapter focuses on developing the container forecasting model for full quay wall containers, the primary objective of this dissertation. This chapter also includes as secondary objectives, proposed models and suggestions for implementing transhipment and empty quay wall containers.

8. Container model development

8.1 Introduction

Chapter 7 consolidated the design requirements from Chapters 2 through 6. This chapter utilises these discussions and analysis outputs to develop the container modelling framework: i.e. inputs, parameters, and forecasting influencers that all culminate in the container modelling process and generate outputs for each one of the functional typologies:

- Primary Objective: Marine Full (Deep-sea)
- Secondary Objectives: Transhipments (Natural and Targeted)
- Secondary Objectives: Empty repositioning (Marine)

The first one on the list is included as the primary objective for this dissertation focusing on full containers and their content. The transhipment and marine empty container typologies contribute to the total quay wall volumes shipped and landed. The information obtained from the analysed datasets provided information valuable to these secondary objectives.

Some of the modelling elements can be rather complex to model, determine values for, or create output datasets that are impossible to work with due to size or complexity. Each section will discuss the robustness of these elements, the accuracy of the values and inputs available and whether it should all be included in the modelling or not. The elements that will provide accurate enough container modelling outputs should be included, without creating a complexity that is not manageable within the planning environment. Part of the model design process was to ensure that the correct elements with the biggest impact were included, and others that only contribute to complexity were shelved for the moment.

A model is only as good as the elements of the model that it uses, i.e. input values, parameter input values and influencer identification. Thus, it would be ideal to have an indication of the confidence level the author has in these modelling elements. It is important to highlight that the author has full confidence in the modelling framework, but due to the extent of the model some of the parameter input values used might be based on subjective or less-researched input data. Thus, the confidence levels shown are for the accuracy of the input values, not in the modelling framework itself. A numbered confidence scale was developed as follows:

- C1: Unsure how to quantify, but convinced of influence.
- C2: Subjective values assigned based on industry engagement and export opinion.
- C3: Values assigned based on subjective extrapolation of statistics.
- C4: Values based on primary research conducted on representative samples.
- C5: Values based on full datasets.

Although no highly scientific calculations of confidence were done on the outputs, the scale indicates the level of confidence the author has in each of the elements used and the outputs generated. For each model segment the modelling elements and confidence levels are tabled and discussed as part of the model definition in the subsections below. Another reason for assigning these confidence levels was that it provides a clear step-wise improvement plan on how to raise the confidence level. Future research on this topic can clearly see where and how improvements can be made, to move from no quantification of input values to sampled datasets or eventually full datasets.

The forecast horizon considered for port infrastructure planning in each case matches the baseline and forecast years discussed in section 2.1.6.

8.2 Modelling elements: Marine deep-sea full containers

The container model segment for this typology deals with freight flows between a port and a local modelling district. The international origin or destination of these flows is not part of the modelled data inputs or outputs, but detail of this kind can inform the trends included in the inputs. The modelling elements derived for marine deep-sea full containers from Chapters 5 and 6 are shown in Figure 8.1 and are discussed in detail below. This excludes the international deep-sea relocation of empty containers that are included in the empty container model segment.

The marine deep-sea typology thus has economic trade flows as the underlying input dataset with detailed import and export tonnes per commodity group. This data is available from the FDM in base year and forecast years. Historic trade values from various economic sources can be used to determine trade volumes for commodity groups between various trade partners in both directions.

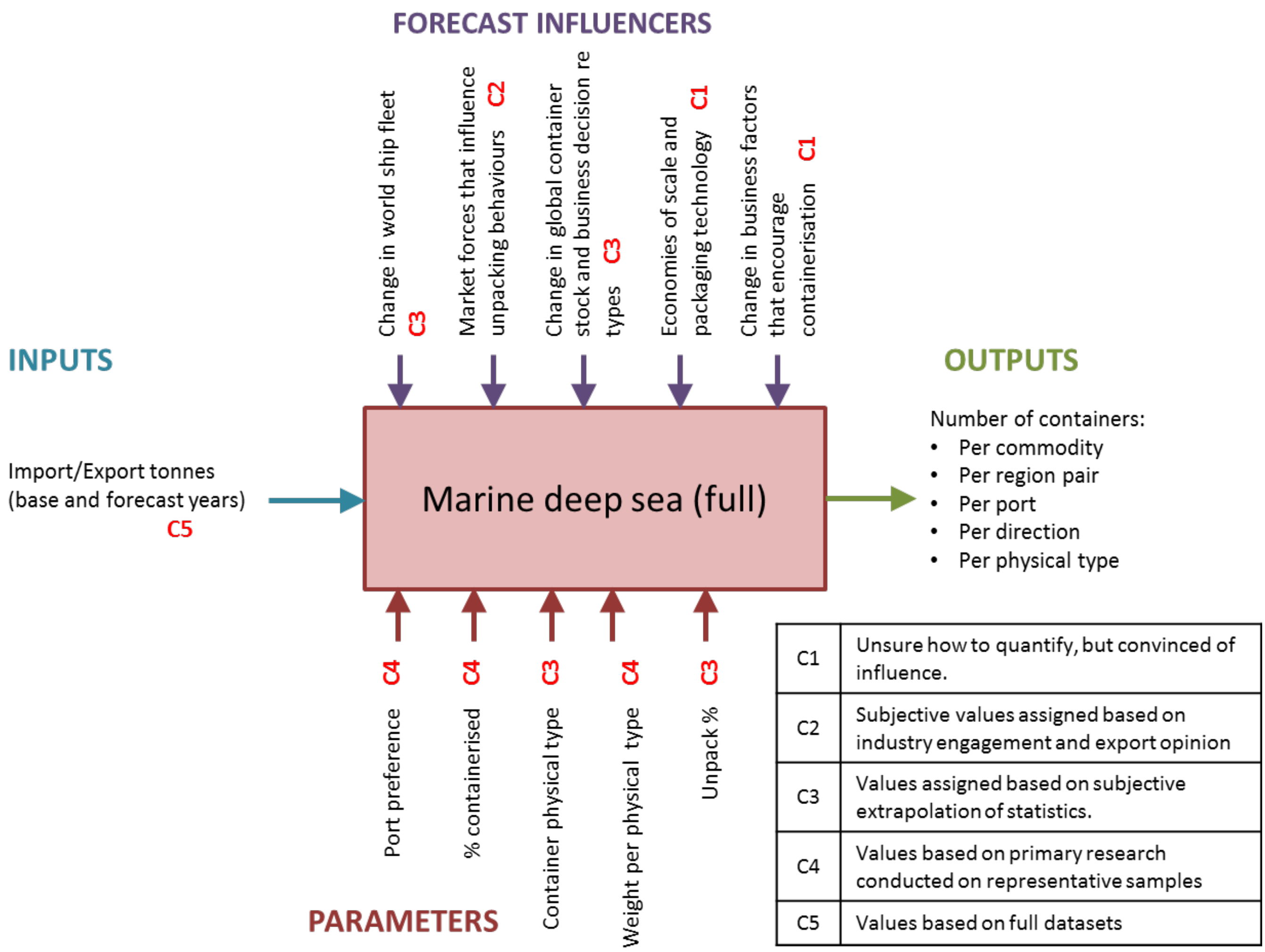


Figure 8.1: Modelling elements for the marine deep-sea full container segment

The parameters included in the modelling are:

- Port preference (F4);
- Percentage containerised (F2);

- Physical container type split (F5);
- Weight per physical container (F6);
- Unpack percentage at or close to the port (U3).

The best way to explain the modelling process and sequence might be to present a short example. If 10 000 tonnes of Commodity X is imported, and based on history:

- It is 100% preferred through Port A.
- If 85% was in containers, then 8 500 tonnes would be imported in containers and 1 500 tonnes imported in bulk.
- If this commodity has typically been imported in the ratio *twenty foot: forty foot: high cube forty foot containers* with a percentage split of *40:40:20* based on tonnes, then the tonnes split for the 8 500 tonnes would be 3 400 tonnes in twenty foot containers, 3 400 tonnes in forty foot containers, and 1 700 tonnes high cube forty foot containers.
- If the average weight per container for this commodity and for Port A based on history was 12 tonnes per NTFU, and 22 tonnes per NFFU this would equate to 283 NTFUs, 155 NFFUs and 77 HFFUs with the 1 500 tonnes in bulk volume.

This is shown graphically in Figure 8.2. These imported containers and bulk freight are available for transport modes to compete over, for surface transport to their final destinations.

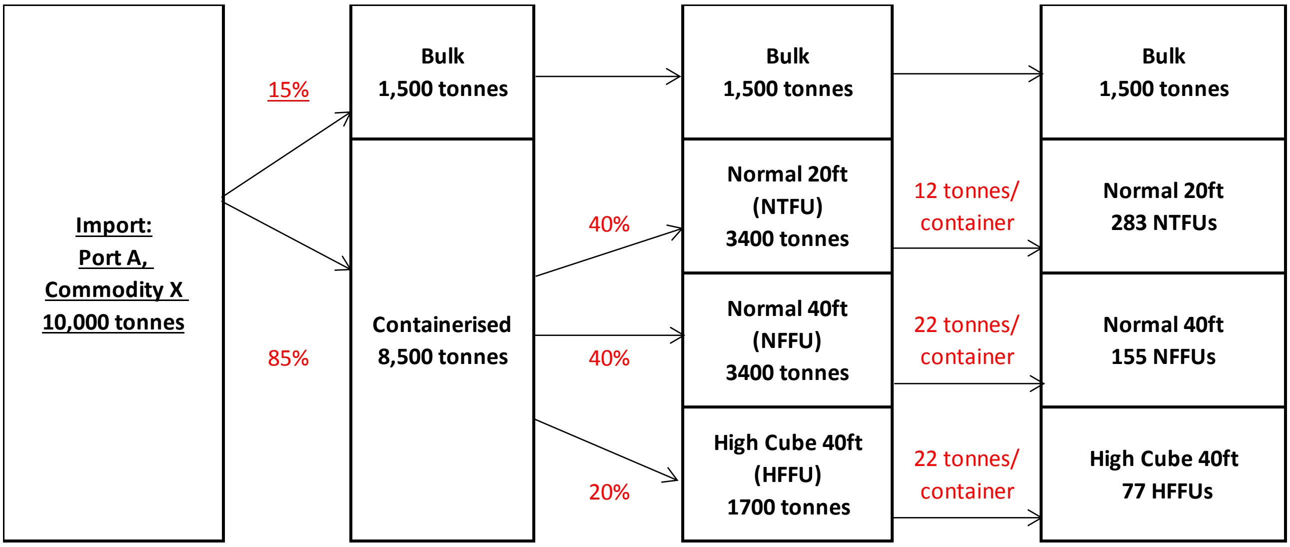


Figure 8.2: Graphic of Commodity X imported through Port A packed into bulk and physical container types

It might be possible to pack more than 22 tonnes into a high cube forty foot container for Commodity X with the extra height available. Thus, there might be a different tonnes per TEU applied per different container types, if this data is available through samples. If nothing is available, then assumptions need to be made based on equivalent or similar container types that are available from the sample.

The next event for the modelling sequence to consider would be the unpack percentage. This parameter is relevant to the surface transport leg for imported and exported goods and is thus not directly relevant to quay wall modelling elements. It was included in this section of the model for the TFR operating divisions to understand what portion of surface freight movements is port linked. Unpacked freight movements are modelled in the FDM as 'virtual' containers to have the port and an inland location as origin and destination, and provide the operating divisions with a view on potential market share they can target. The focus group participants indicated that a significant portion of the containerised imports is unpacked and exported containers packed close to the port. They also believe that if rail wants to compete for this transport they need to make it attractive for freight owners to move completely packed containers and thus stop the packing/unpacking phenomenon.

Although some indications of current pack/unpack percentages are available for exported/imported containers respectively from the Ethekweni study (Royal Haskoning DHV; IMANI Development, 2013) as well, a more detailed research project is proposed to define accurate current and future values for this part of the model. It can be said for certain at this stage, though, that the unpack/pack parameter is very much applicable to marine deep-sea containers and with current road/rail market forces, it will prevail.

Influencers might significantly change the values used for the parameters. In the example above the containerised percentage or the split between container types are based on historic values. This provides a baseline for trends to be applied on. The influencers might change these percentages and other values significantly over the forecast horizon (medium- to long-term). It is thus important for the modelling team to monitor these influencers over time to incorporate changes to the model outcome. The design requirements and especially the attention points from Table 7.1 were regrouped to define high-level influencers that need to be monitored for the marine deep-sea functional typology. These influencers include the following:

- Changes in world vessel fleet: A significant reduction in bulk ships that can transport certain commodities will force these commodities into containers and increase the percentage containerised. An over- or undersupply of any ship type (container, reefer, bulk, tanker) could force large volumes into the other types of ships if they can transport those commodities.
- Market forces that influence packing and unpacking of containers: Similar to the above business factors changes in reliability, cost and lead times could impact decisions to pack/unpack close to the port or at the origin/destination for exported/imported containers respectively.
- Changes in global container population or business decisions on the types used: It has been mentioned that internationally mostly forty foot containers are manufactured and preferred. Thus, the availability of twenty foot containers might reduce over time, leading to an increased use of forty foot containers.
- Economies of scale and packaging technologies: The extent to which the trend continues to pack more of every commodity into containers will influence the modelling outcome. This will impact the weight per TEU applied to tonnes imported in containers. Aspects to be considered are port independence, direction independence, and TEU equivalence over different types as discussed in sections 5.5.4 and 6.3.2.
- Change in business factors that encourage containerisation: A higher risk is involved with shipping higher-value goods outside of containers. Also changes in comparative pricing of hinterland transport modes containerised or in bulk will impact the location of pack/unpack events.

The above method can be applied to any number of input datasets where port planners have import and export tonnes available for multiple years and growth scenarios. The output the model generates is:

- the number of containers
    - per commodity
    - per region pair (origin and destination)
    - per port
    - per direction (import or export)
    - per physical container type.

This container detail can be summed over all commodities for a number of different views to, for example, determine the number of modelled full containers through Port A in both directions for a specific year. The timing for infrastructure expansion projects can then be planned based on when the forecast volumes would exceed the current available berth, lifting equipment or storage capacity. The confidence levels of the modelling elements for this modelling segment are shown in Table 8.1.

The import and export tonnes are based on full datasets obtained from well-known and countrywide respected economists. They have been involved in the process for several years, thus the high confidence level of C5. The shipping line sample datasets were analysed to obtain detailed answers on port preference, percentage containerised and weight per TEU per commodity. The multiple years of data received and analysed together with the high sample percentage provides confidence to a level of C4. The shipping line sample data did not provide full detail on physical type split and therefore this confidence was dropped to a level of C3. Some subjectivity by the research team was possible in these elements. The unpack percentage was also done through extrapolation of a limited dataset, thus C3 as well. Although the unpack percentage is a domestic extension of the quay wall model and could be argued as not part of this dissertation's core scope it is included in the modelling framework. It was however not considered when the confidence level of C4 was chosen for the base year model outputs.

Table 8.1: Confidence level: Modelling elements for Marine deep-sea full containers

Functional Typology	Modelling element	Modelling aspect	C1	C2	C3	C4	C5
Marine Deep-sea Full	Inputs	Import/Export tonnes (base and forecast years)					X
	Parameter values used	Port preference				X	
		Percentage containerised				X	
		Weight per TEU				X	
		Physical Type Split			X		
		Unpack percentage (For domestic intermodal)			X		
	Forecast Influencers	Change in world ship fleet			X		
		Market forces that influence packing/unpacking of containers		X			
		Change in global container stock and business decisions regarding type			X		
		Economies of scale and packaging technology	X				
		Change in business factors that encourage containerisation	X				
	Outputs: Base Year	Number of containers: per commodity, per region pair, per port, per direction, per physical type				X	
	Outputs: Forecast years	Number of containers: per commodity, per region pair, per port, per direction, per physical type			X		

The forecast influencers are based on subjective extrapolation of the industry engagement, thus the lower confidence levels of C2 and C3 were mostly assigned. The last two influencers in the table are listed as C1 since no indicative datasets were available. The literature studied in Chapters 3 and 4 provided sufficient evidence to include these as influencers, but no clear values and impact could be derived. Further research in these matters is required. The confidence in outputs for forecast years was also reduced to C3 due to the lack of in-depth knowledge obtained from industry to date.

In order to increase the confidence level of the marine deep-sea modelling input elements and output values, the following aspects need future research attention and analysis from future databases:

- Ceiling percentage containerised per commodity: the notion existed with some focus group participants that some commodities might be containerised to a different ceiling percentage other than 100%. The shipping line and TNPA bulk data did not highlight any such commodities that indicated that it stagnates at a particular containerisation percentage other than 100% or sporadic containerisation of commodities preferred to be shipped in bulk.

- Ceiling weight per container type per commodity, growth period: Focus group participants commented that in most cases a further 5–10% weight increase in containers is possible due to improved packaging technology and product design. They expect these changes to happen mostly in the next five years or at the longest the next ten years. The weight per container can thus achieve this ceiling level over this time period. Some containers in the datasets analysed were highlighted as anomalies with situations reaching double the average or normal container weights. This was usually for single containers moved through irregular port and trade partner combinations. The data accuracy of these could thus be questioned and these were often deemed as anomalies. The dataset could, however, be used to deduct ceiling weights per container types for each commodity based on historic movements. This needs further analysis and more datasets to clarify.
- Container physical types: Physical types have been determined from historic data that mostly are provided as a split between twenty and forty foot containers either as normal or as reefer containers. Transnet port planners use nine physical types described in section 5.5.5. To enable more consistent modelling practices, commodities have been classified into physical type families. For each physical type family a split into the various physical types was determined for imports and exports. Due to this addition commodities can be classified into preferred physical types or a combination of various physical types. Current values for the splits have been derived from the data available and the analysis done. Further research and inputs from industry are required to improve the accuracy on this classification and the preferences per commodity. More accurate future values for 5-year and 30-year forecasts can then be estimated.
- Pack/unpack location: This phenomenon also needs to be further analysed to understand the influence this has on market share of surface freight modes in South Africa.

Over and above these key aspects, continued further research into the influencers is required.

8.3 Modelling elements: Transhipment containers

Transhipped containers add up to the total port volumes, and historically showed to be 15–18% of full containers. Quay wall infrastructure and capacity need to be created and maintained for these containers as well. The datasets received from various industry sources provided little input and insight into this container typology. Due to this, other devices had to be used to determine the modelling elements. One method was time dedicated to the literature study in Chapters 3 and 4. Many aspects in this chapter provided insights into scenarios related to transhipment containers.

As mentioned before, transhipments are split into two segments. Natural transhipments are due to the origin or destination of the freight being to or from a neighbouring country that does not attract enough freight to justify a dedicated direct shipping route. Strategic/targeted transhipments are from two trading partners with direct routes with South Africa, but not with each other, and a container can be relayed between these direct shipments at a South African port.

Transhipment containers are in essence freight movements not related at all to South African economic activity. The container model segment for this typology deals with freight flows thus not part of the South African economy, but due to the proximity of the freight flow past the South African coastline. South African port infrastructure sometimes does get involved in the shipping route and generate income from transhipments. To establish a detailed model to the level of detail of marine deep-sea, inputs would be needed for the following key drivers:

- Freight Owners prefer direct shipments due to the following logic:
    - Lead times are shorter,
    - Transit time from their premises to the final market is reduced,
    - Port delays could have a more significant impact if another port is added to the route.
- Shipping lines are making the routing and transhipment decisions based on their economies of scale. If a ship will not be utilised fully on a particular route (A to B), they will not service that particular route directly, and freight owners will need to use transhipment to transport freight from point A to point B.
- Direct routes (frequency): A shipping line would require a minimum volume to service a direct route. Examples found were some shipping lines offering a direct route from Cape Town to the USA in the citrus season due to these additional volumes, while outside this season transhipments via Europe is required to get freight to the USA.
- Ship size (efficiency): As trade volumes increase, direct shipping becomes a viable option between two ports. However, as the ship size for a route increases, the relative volume needed to justify the direct route increases as well. The bigger the ship, the more cost-efficient; however, less frequent the visits, the less direct routes it can service. Smaller ports also cannot service larger ships as efficiently and longer ship turnaround times impact the ship's return on asset for the shipping line.
- Port cost to call/efficiency: The cost for a ship to stop at any port is significant. If the revenue a shipping line can generate from stopping at this port is not justified through enough volume, or if the ship is not turned around quickly enough, the return on asset might not justify the ship making the call at that port in the first place.
- Port capacity and efficiency upgrades: As port expansion projects are finalised, more routes become feasible with existing ship sizes. Thus, this model will have to keep in mind the port projects close to the South African port network.
- Global trade shifts: As global trade patterns and trends shift, new volumes of freight might be sufficient to open up new routes that shipping lines can service efficiently with the existing fleet.

Global trade data can act as inputs for this section of the container model, and would include tonnes per commodity between countries that are 1) deemed as natural transhipments due to a link to a nearby African country, or 2) deemed as strategic transhipments due to it being southern hemisphere freight moving past the South African coast. Trademap data (International Trade Centre, 2017) are available online as follows:

- Origin and destination countries,
- Commodities (according to HS4 code level),
- Annual values (value can be translated to tonnes by means of average commodity prices).

The container model segment for this typology follows a two-phased approach:

- The first phase utilises the tonnes per commodity and duplicates the marine deep-sea typology process to containerise these tonnes for each commodity according to percentage containerisation, container type allocation and weight per TEU. Average values from the South African marine deep-sea parameter input values can be used where possible, and this process has been explained.
- The second phase identifies which of this African and global South-South trade could be attracted to South African ports as transhipments. The parameters explained below are used to determine which portion of this global container subset would be attracted and has an output of transhipped containers.

The two-phased approach is shown diagrammatically in Figure 8.3. This diagram indicates the two different sources of input, the parameters explained below and the outcomes for natural and strategic transhipments. The process followed will be explained after the parameters have been defined.

The parameters considered for establishing the freight that could be attracted to South African ports as natural and strategic transhipments are the following:

- Capture potential: This is an indication of the number of boxes of global trade with close African countries that can be captured at South African ports for natural transhipments. For example, trade between Brazil and Namibia can be captured as natural transhipments at the Port of Cape Town. As long as not enough volumes are shipped for frequent direct shipping between Brazil and the Port of Walvis Bay, this would be a potential for capturing this freight, or if the port's physical dimensions cannot accommodate the size of the preferred ship on that route. A value is assigned to each destination port along the East and West African coast, based on the port characteristics and capabilities. This value is between 0 and 1 based on the operational excellence, capacity, draft and physical limitations for ship size and the ability to handle containers. A value of 1 indicates that all traffic will be captured by a South African port, while a value of 0 indicates that none will be captured.

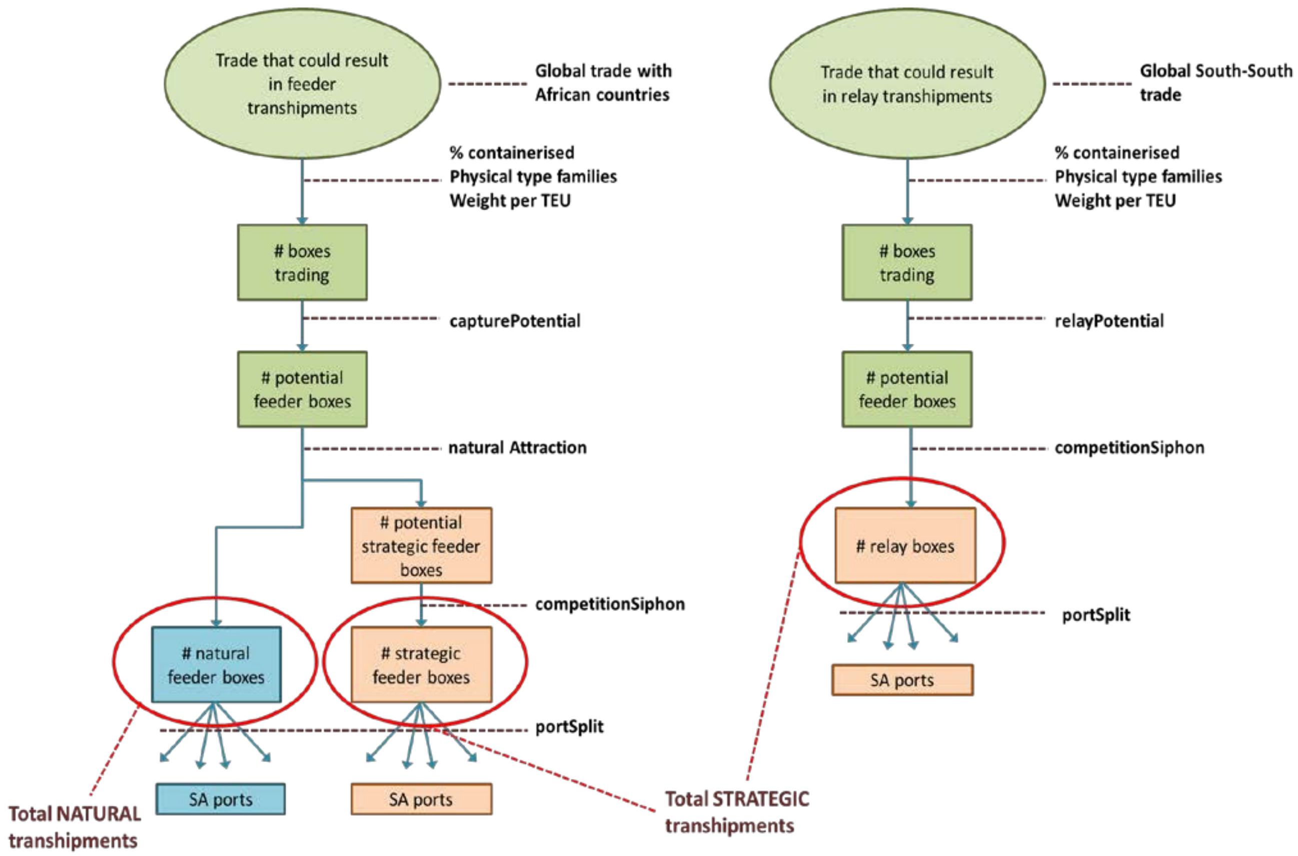


Figure 8.3: Diagrammatical representation of the second phase of the transhipment model segment

- Natural attraction: Ships already carrying goods to South Africa and making a port call at a South African port would not be likely to visit another nearby port for small volumes. For example a ship from Brazil with containers for both the Ports of Cape Town and Walvis Bay, would prefer to only visit one of the ports and return on its route. If a very much smaller quantity of containers is destined for the Port of Walvis Bay it would also offload these at the Port of Cape Town. South Africa has a much bigger international trade footprint than its coastal neighbours. This parameter is based on the strength of South Africa's current trade partnerships.

- Relay potential: This is the fraction of relay shipments that could potentially be captured based on whether an international trade route is passing South Africa. Typically this would be between the mentioned Southern hemisphere trade partners, or so called South-South trade. This is also a value between 0 and 1, and provides an indication of the fraction of freight that could be captured. The value is based on the nature of the desired shipping route between trade partners and is a function of frequency of vessels, vessels' sizes, and volumes of shipments between trading countries.
- Competition Siphon: This is a measure of South African ports' competitiveness as a transhipment hub relative to other ports in the region, such as Madagascar or Malaysia. This measure is based on vessel size and physical limitations of South African ports versus these competition ports, the cost of ships calling at these ports, the operational efficiency and relative ease of doing business with these ports for the shipping lines. Information technology and administrative efficiency all come into play with this type of comparison. The number is again a value between 0 and 1 indicating the percentage of potential containers that South African ports would attract.
- Port split: This is an indication of the potential transhipments that any one of South African ports would attract. This is based on the strategic intent assigned by Transnet, the capability of the port to handle transhipments in terms of lifting and storage capacity, but also ship size and the port's physical limitations.

The process followed is explained step-by-step in Figure 8.3. This process has three branches that contribute to the two different aspects of natural and strategic transhipments as follows:

- *Natural transhipments*:
    - Global trade with African countries are used as input data.
    - This trade is transformed into container numbers using the marine deep-sea methodology.
    - The capture potential parameter value is used to determine which of these containers would be deemed feeder boxes. Feeder boxes are the containers that would use natural transhipment with coastal ships from nearby ports to reach their final destination.
    - The natural attraction parameter value is used to determine which of the feeder boxes would be natural feeder boxes for South Africa due to South Africa's existing strong trade partnerships with the same countries.
    - The port split parameter is used to divide natural feeder boxes between South African ports.
- *Strategic African trade transhipments*:
    - The same process as with natural transhipments are followed, except that Transnet might decide to market a port to shipping lines with special rates to attract additional feeder boxes over and above the natural feeder boxes. To enable this, these ports need to be seen by shipping lines as a better alternative, and here the competition siphon parameter is used to generate strategic feeder boxes.
- *Strategic South-South trade transhipments*:
    - Global trade between South-South countries are used as input data.
    - This trade is transformed into container numbers using the marine deep-sea methodology.
    - The relay potential parameter value is used to determine which of these containers would be deemed relay boxes. Relay boxes are the containers that would use relay transhipment with deep-sea ships on relay South-South shipping line routes.
    - The competition siphon parameter is used to allocate a percentage of the relay boxes passing South Africa to South African ports.
    - The port split parameter is used to divide natural relay boxes between South African ports.

The following aspects need to be continuously monitored as influencers to the transhipment model:

- African port development: The capture potential could change quickly when port investment in new infrastructure becomes operational. Shipping lines can then decide to change shipping routes to visit these ports if they deem enough volumes are available.
- Growth or decline in international trade: South African international trade relationships in combination with our coastal neighbours' trade relationships could have an impact on natural attraction of shipping routes to our ports vs coastal neighbour ports. If their trade volumes should surpass our trade volumes, shipping lines would divert their shipping routes to competing ports and use natural transhipment to South African ports.
- Development of competing transhipment ports: This has an impact on shipping line route decisions and includes aspects such as port capacity, efficiency and overall performance.
- Development of South African transhipment ports: This has an impact on shipping line route decisions and includes aspects such as port capacity, efficiency and overall performance. This includes the performance of South African ports relative to each other, since shipping lines might prefer one port over another due to reasons as described in the competitive behaviour discussed in detail in Chapter 2.
- Change in global shipping routes: The global shipping routes need to be tracked to understand the potential origin destination pairs that are available for direct shipments. If global shipping routes passing our coast line in the South-South trade routes become more frequent, then relay potential could drop due to the potential for direct shipping routes.

The output that the transhipment model generates is:

- the number of containers
    - per commodity,
    - per region pair,
    - per physical container type.

To incorporate all of these elements is a significantly more complex model than just following the current percentage of full containers transhipped per port. The datasets analysed do not provide the necessary inputs. The modelling elements derived for transhipments from aspects of Chapters 3, 4, 5 and 6 are shown in Figure 8.4 and were discussed in detail above.

The confidence levels of the modelling elements for this modelling segment are shown in Table 8.2. The input data from Trademap are available, fairly easy to find, but do take considerable effort to download and process for all the relevant countries. The only concern might be the accuracy of the average price per commodity used to translate the traded value to tonnes. Several of the parameter values and influencers are at this stage fairly irrelevant due to the low level of competitive ports along the sub-Saharan African coastline. Parameters in this category are natural attraction, relay and capture potential and competition siphon.

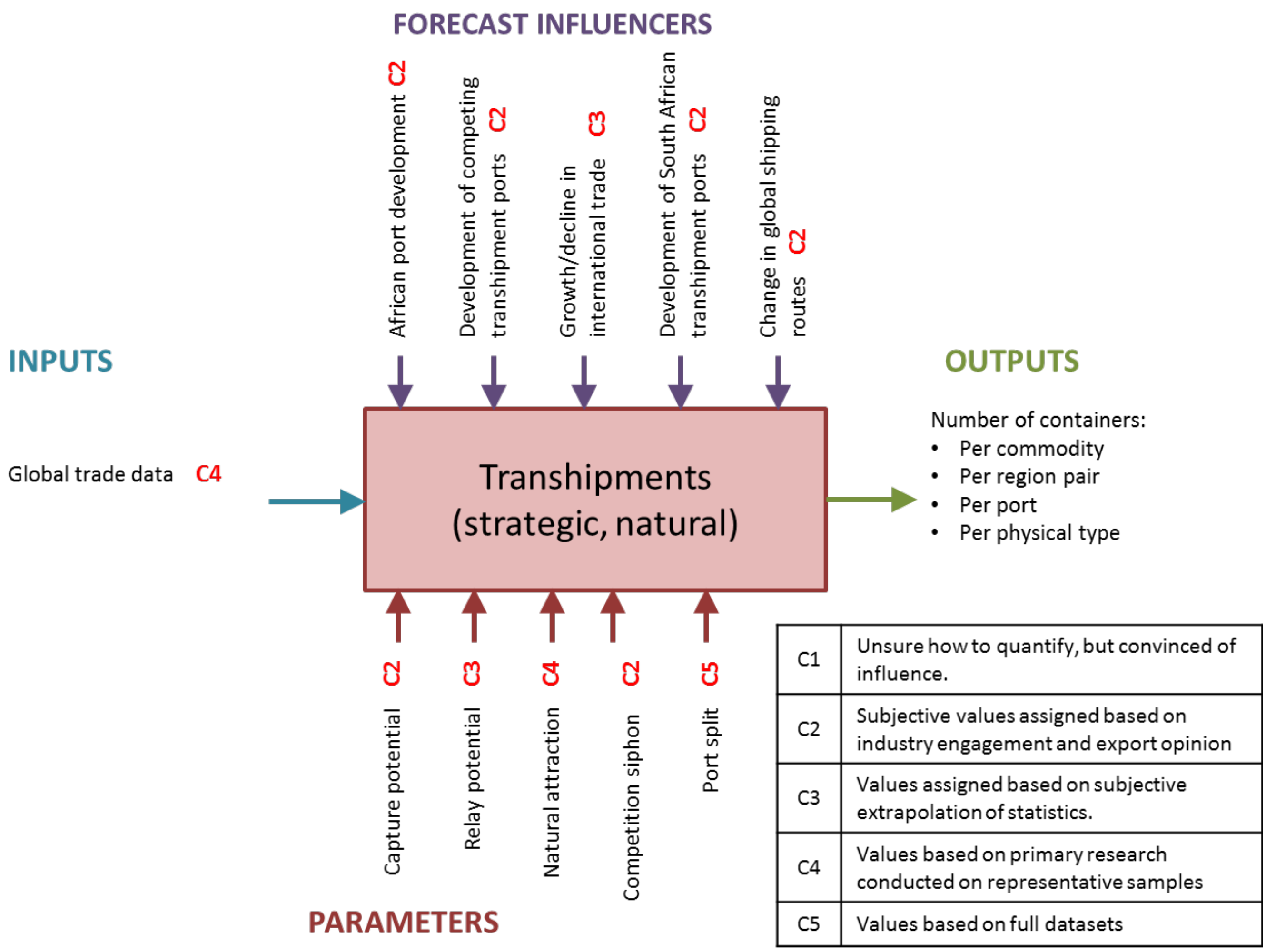


Figure 8.4: Modelling elements for the transhipment container segment

Table 8.2: Confidence level: Modelling elements for transhipment containers

Functional Typology	Modelling element	Modelling aspect	C1	C2	C3	C4	C5
Transhipment Containers	Inputs	Trademap data (OD volumes per country, HS4 level)				X	
	Parameter values used	Capture potential		X			
		Natural attraction				X	
		Relay potential			X		
		Competition Siphon		X			
		Port split					X
	Forecast Influencers	African port development		X			
		Growth or decline in international trade			X		
		Development of competing transhipment ports		X			
		Development of South African transhipment ports		X			
		Change in global shipping routes		X			
	Outputs: Natural	Number of containers: per commodity, per region pair, per port, per physical type			X		
	Outputs: Strategic	Number of containers: per commodity, per region pair, per port, per physical type			X		

These parameters have mostly been given a confidence of C2 due to its values being determined through discussions with a limited number of industry experts. Relay potential has been given a C3 confidence level due to the history in the shipping line coastal data providing coastal export data. The transhipment port split for South Africa is based on a full database from TNPA and thus was given a C5. The influencers were all given a C2 after discussion with port planners at Transnet, with international trade growth or decline obtaining a C3 due to available economist inputs on the project.

The outputs for both natural and strategic transhipments were assigned a value of C3, indicating some confidence in the outputs, but this is mostly due to a lack of current competition for this, and it takes time to establish capacity to be able to compete.

It must be mentioned that this could be an extensively complex model to execute that proves little improvement in accuracy over a much more robust method, especially if the confidence in the parameter values available are low and the accuracy of the outputs are in question. The more complex model was explained to compile a starting point for further research from the knowledge gained from this dissertation. Due to the complexity and effort required to collect all the input data, a more robust method could be considered. At this stage it might be considered to do both a robust and a detailed model and obtain a level of confidence through evaluating the outputs over time and comparing forecasts with actual values over the years. Once further research has provided more detailed input values and a higher level of confidence has been established, the more complex model would be higher in accuracy and could be used alone.

This robust method would be to review historic transhipped containers per port as found in section 5.5.7.1 and include this in the container model for the transhipment segment. This can be done on a container volume basis or alternatively the norm found during the literature review can be followed where a percentage of full containers is used as the guiding principle. The logic here is that the more full containers are loaded and offloaded, the more transhipment containers might accompany these full containers.

This proposed model excludes the international relocation of empty containers trough transhipments that are also not included in the empty container model segment due to it using the local containerised economic activity as input values. These are however included in the TNPA data for empty quay wall containers and in the calculation of the empty containers as a percentage of full containers that cross the quay wall. Thus transhipped empty containers will need to be modelled using a robust technique based on a historic percentage of empty transhipped containers per port, since it is not related to any economic activity and would thus also not be included in the Trademap database.

It is important to note that transhipments only affect the ports and not any inland or domestic coastal modes of transport. Thus, it need only be modelled per South African port.

8.4 Modelling elements: Empty containers

Empty containers add up to the total port volumes. Quay wall infrastructure and capacity need to be created and maintained for empty containers as well. An empty reposition model needs to be established for the land-based empties to be able to understand the demand for empties across the quay wall. This section will attempt to do just that.

The datasets received from various industry sources provided little input and insight into these container typologies since they do not contribute to any economic activity. Due to this, other devices had to be used to determine the modelling elements for this functional typology. Some effort was dedicated to this topic in the literature study in Chapter 4 with some aspects in that chapter providing insights into empty container scenarios. Globally, empty containers contribute 16–19% of the full containers moved over the last decade.

For South Africa the TNPA numbers showed in Chapter 5 that exported empty containers contribute 17–21% of full containers, and import containers contribute 8–12% of full containers over the 5-year dataset analysed.

An empty container is essentially required at the origin of every full container, and originates at the destination of every full container. Empty container supply and demand can thus be understood completely if full origin-destination information is available on all full container movements. The modelled values for the full containers can be used to estimate the empty containers. A balancing act needs to be done between the supply of and the demand for empty containers per container physical type. In this case the supply of empty containers is the sum of imported and domestic empty containers. The demand for empty containers is the sum of export and domestic empty containers.

The modelling elements derived for the empty container segment from aspects of Chapters 4, 5 and 6 are shown in Figure 8.5 and are discussed in detail below.

The inputs for the empty container model are the outputs generated by other container model segments:

- Marine deep-sea outputs (from section 8.2),
- Marine coastal shipping outputs (concept model developed in Appendix G),
- Domestic intermodal freight outputs (inputs from model developed in other project).

These outputs could indicate empty container supply and demand imbalances due to trade imbalances per location (country/province/district level) and due to ownership policies. As seen in the discussion group feedback in section 6.3.7, most of the shipping containers in circulation are owned by shipping lines. They only allow their own containers to be used on their own ships, and thus a higher percentage of empty containers can exist due to this on both a quay wall and domestic level. Shipping lines also do not allow triangulation, and thus an empty container in the hinterland might need to be returned to their depot at a port for structural checks before it can be used again. This causes extra complexity in empty container movements over and above the normal supply and demand balance exercise proposed here.

The only parameter identified is the cost parameter involved for every transport mode in moving an empty container from the point of supply to the point of demand. This could be different for different regions, different container physical types and different modes. The higher the cost parameters the least likely a container would move far from its origin, but would be used at its closest demand point. The regions used for this modelling are 19 economic regions defined as part of the economic input-output model and are a consolidation of the 372 districts into regions like, Gauteng, Free state, Cape metropole, winelands, etc. It roughly divides some of the 9 provinces into smaller areas that empty containers would circulate within and the model assumes that supply and demand would gravitate towards being solved within these economically active regions.

The only influencer identified is the change in cost factors per transport mode over the forecast horizon. A rise in costs would reduce the likelihood that containers would move far, while a reduction in cost would 'allow' empty containers to move further to demand points. The cost of moving containers between regions acts as a factor that discourages containers from moving at all. The modelling process implemented is a Linear Programming (LP) solver based solution to find the match between supply and demand of empty containers per region and per physical family type. The same process can be repeated for all forecast years and scenarios. This sounds logical and easy to execute, however, some levels of complexity exist within this that makes the solver rather difficult to execute. The detail of this will be discussed later in this section.

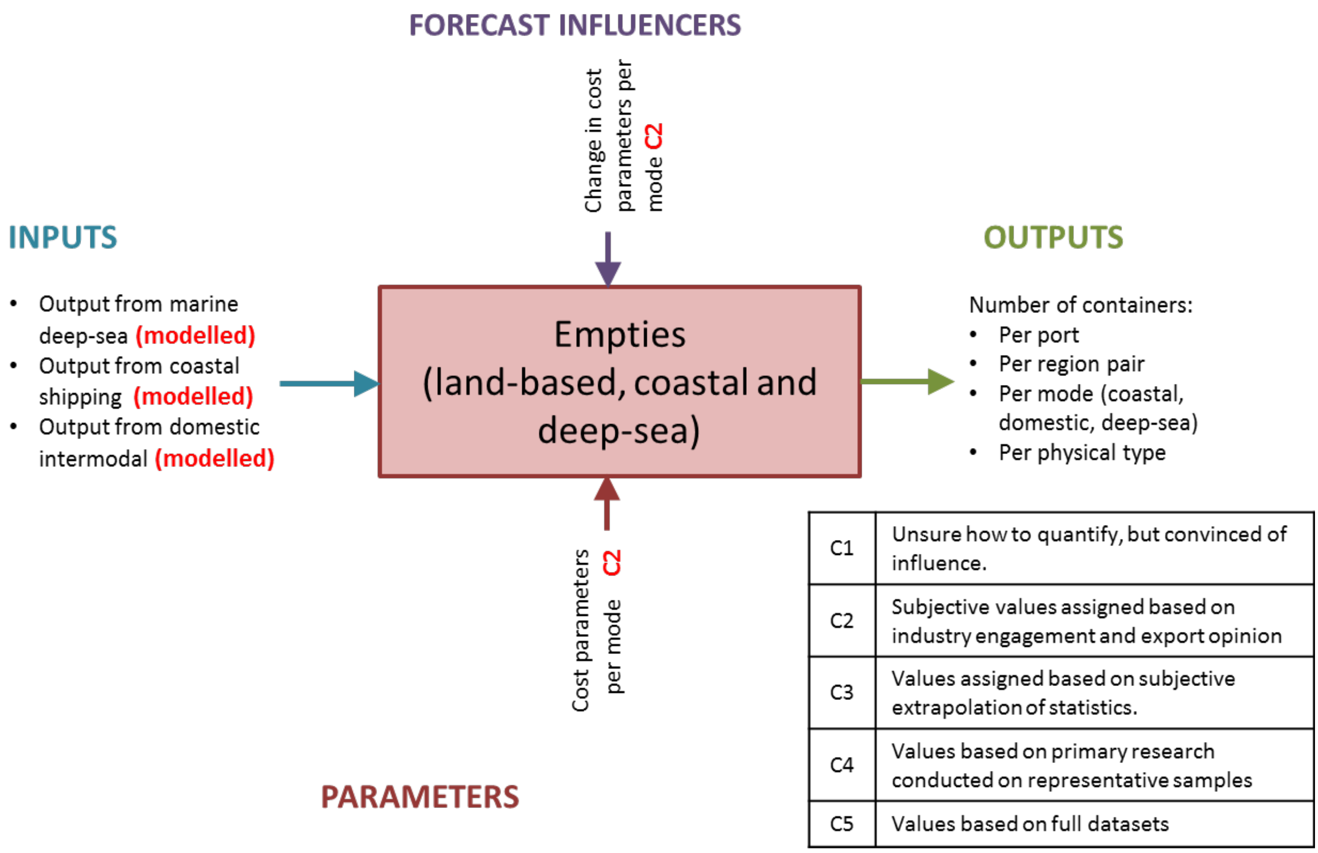


Figure 8.5: Modelling elements for the Empty container segment

The output that the empty container model generates is:

- the number of containers
  - per region pair,
  - per mode (coastal, domestic, and deep-sea)
  - per physical container type.

One critique of this model is that it uses all the other modelling segments' outputs as input values. Thus, it can only be less accurate than the least accurate of all the other model segments.

An important aspect to highlight here is the time frame. Long term (annual) supply and demand balance might not translate to short-term (week-by-week) balance. Due to commodity seasonality and peak shopping seasons severe demand peaks might not coincide per physical container type, which could lead to a large-scale requirement for empty container movements. The long-term view and annual supply and demand balancing proposed here for empty containers numbers are thus most likely a minimum value and could be much bigger due to short-term challenges.

Another aspect that adds complexity to the container model is the packing and unpacking of containers closer to the port. The origin-destination combinations of freight flows used as inputs for the empty container model do not consider this, but expect containers to move to the final destination for imports and from the origin for exports. A correction has been made to the domestic model to compensate for this phenomenon, but the complexity does provide some issues with the Solver approach.

The model proposed here provides not only quay wall empty container volumes per port, but also the origin-destination movements across the country. This extended model will benefit TFR in that they can target specific empty container movements for increased market share. It does, however, add a level of complexity that might deem the execution difficult and the accuracy unacceptable.

The confidence levels of the modelling elements for this modelling segment are shown in Table 8.3.

Table 8.3: Confidence level: Modelling elements for empty containers

Functional Typology	Modelling element	Modelling aspect	C1	C2	C3	C4	C5
Empty Container s	Inputs	Marine deep-sea outputs				X	
		Marine coastal shipping outputs			X		
		Domestic intermodal freight outputs		X			
	Parameter values used	Cost parameters per transport mode		X			
	Forecast Influencers	Change in cost factors per transport mode		X			
	Outputs	Number of containers: per region pair, per mode, per port, per physical type		X			

The Marine deep-sea outputs were deemed level C4 in an earlier section, and the coastal shipping outputs a confidence level of C3 (Appendix G). The domestic intermodal was deemed a C2 due to some of the complexities around some of the input values. The cost parameters per transport mode is not that readily available for the complete set of routes and modes and vehicle types, thus a level of C2 was assigned for both current parameter values and future influencers. The outputs were deemed to be a low value of C2 as well due to the input uncertainty, and the origin-destination disconnect caused by the pack/unpack phenomena.

A much easier method to use would be calculating empty containers as a percentage of full containers per port. This method was discussed in literature and in TNPA data analysis and can provide quay wall empty containers per port in a much simpler calculation. The inputs for such an approach would be analysing past trends and using that to predict the medium-term future. This does not help to solve the flow of domestic empty containers, though. This would, however, disconnect the modelling from the risk of depending on model outputs that are not included in this dissertation.

8.5 Conclusion

This chapter has developed the modelling frameworks and discussed the modelling process for three functional typologies. The inputs, parameters, process, forecasting influencers and outputs for each of the defined functional typologies was discussed separately and a confidence level was given to each of these aspects. The confidence levels provide an indication of the current status of the parameter values and values for influencers obtained through literature review and data collection and analysis in Chapters 2, 3, 4, 5 and 6. The modelling design requirements consolidated in Chapter 7 were implemented and the three models are ready to be used. Although excluded from the scope early on in this dissertation, a proposed model for coastal shipments was included in Appendix G.

The biggest concern is with the empty repositioning model. The logic makes sense, but the dependency on other models and subsequent uncertainty and inaccuracies obtained through the modelling process guides the author towards using an alternative method for empty quay wall containers. A percentage of full containers per port would be suggested as a potentially more accurate alternative.

The next chapter ventures into verification and validation of the quay wall container forecasting framework.

9. Container model verification, validation and illustrative forecasting results

9.1 Introduction

This chapter deals with the verification and validation of the container modelling framework. The verification of the requirements and how they are satisfied by the container modelling framework provide the answer to whether the framework adheres to the design requirements provided in consolidated format in Chapter 7.

The chapter then discusses the validation process followed to provide the confidence in the modelling results and to illustrate whether this approach would deliver on its objectives to be more accurate than alternative methods used. The validation first takes an approach of comparing results from different forecasting methods and establishing their relative accuracies. Secondly, a comparison of forecasting results for specific container ports was included to indicate when additional capacity would have been required at the time.

The chapter then illustrates typical results from the proposed model outputs to further demonstrate the functionality built into the three functional type models proposed in Chapter 8.

9.2 Model verification

Model verification relates to whether the modelling framework has been built according to the specifications. Boehm (1984) argues that verification is building the system right, thus doing what the designer should, and validation is whether the right system is built, thus whether the system is doing what it should. To verify if this has been done accurately, Table 9.1 through Table 9.5 illustrate how the different categories of design requirements defined and consolidated in Table 7.1 have been met in the model's three functional typologies.

Table 9.1 shows the user requirements mainly focusing on the outputs that the model should generate for the typical users of the model. Port planners would receive outputs per disaggregated commodity groups to enable them to further validate demand per significant commodity groupings. Being able to do this verification step will ensure a level of confidence and comfort with users in the outputs generated by the model. Including the container physical types in the modelling outputs would also add to users' ability to plan for specific quay wall container handling equipment.

Table 9.1: Model verification discussion for User requirements

Req. ID	Model requirement	Marine Deep-sea	Transhipment	Empty
U1	Disaggregated commodities	This is the key requirement for this proposed forecasting approach and thus detail commodities are incorporated throughout.	N/A	N/A
U2	Container physical types	Part of the outputs generated by all three models: Accuracy requires more detailed input data, but included as higher level physical type families at this stage		
U3	Container unpack position and transport modes (Not included)	N/A	N/A	N/A

Table 9.2 indicates model verification for design restrictions. The major objective identified with design restrictions was that the proposed model needs to interact with various other freight surface models providing inputs and using this model's outputs. These design restrictions identified were adhered to in the modelling frameworks developed in Chapter 8, by incorporating the same commodity disaggregation, and designing the parameters to be applied to the input data according to the same forecasting year pattern used by other related surface freight models.

Table 9.2: Model verification discussion for Design restrictions

Req. ID	Model requirement	Marine Deep-sea	Transhipment	Empty
R1	Disaggregated commodities adhere to related models	This is a key dimension of this forecasting approach. No new commodity groupings were proposed based on the analysed input data.	N/A	N/A
R2	Parameters applied to origin-destination data	Design was done to be applied to existing O-D flow data as percentages applied to the existing volumes in tonnes.	N/A	N/A
R3	Forecast year breakdown	FDM pattern accepted (i.e. base year and forecast years with intervals as shown in multiple result and output graphs provided in section 9.4)		

Table 9.3 lists and describes the model verification for the functional requirements. The functional design requirements identified, led to the model parameters included in the forecasting frameworks. This is the heart of the proposed model and determined the major advantages the proposed model would have over forecasting techniques used by other modellers in the past and described in Chapter 3. These parameters provide a far more detailed approach than the high-level approaches suggested in literature.

Table 9.3: Model verification discussion for Functional requirements

Req. ID	Model requirement	Marine Deep-sea	Transhipment	Empty
F1	Spatial disaggregation	Model design to breakdown detail per origin and destination port, locally and international. The input data analysed provided detail for all other functional requirements at a local and international port level. Starting values and trends were established for all the quay wall functional requirements per South African container port.		
F2	Percentage containerisation	Based on historic data per commodity for total quay wall volumes per port (with F4)	N/A	N/A
F3	Disaggregated commodities	This is the key change to this forecasting approach and thus incorporated throughout	N/A	N/A
F4	Port preference	Based on historic data per commodity for total quay wall volumes with (container and bulk split for F2)	N/A	N/A
F5	Container physical types	Needs more detailed data, but included as physical type families. Change in world container population will influence this.	N/A	N/A
F6	Weight per container type	Based on detailed historic data, applied per commodity per physical type family.	N/A	N/A

Detailed starting values for these parameters and future medium-term trends were derived from the input data obtained primarily from shipping lines and TNPA, supported by data from other parties. Further research into some of these parameter values would be required to improve the confidence levels indicated in Chapter 8. Further research would increase the confidence levels of the parameter input values used in the modelling, but the proposed parameters are deemed sufficient to accurately forecast full quay wall container volumes.

Table 9.4 shows the model verification of attention points. Several attention points were identified and incorporated into the model as influencers. These influencers are mostly related to trends in the supply- and demand-side of the container infrastructure landscape as described in Chapter 4. Large-scale shifts in any one or a combination of these attention points could lead to a significant change in the values used for parameters in the modelling and subsequently change the volumes for all three typologies. For example, if large-scale container terminals are built at the coast connecting the east–west corridors proposed in Chapter 4 with a high level of port hinterland integration by means of road and rail infrastructure development, it could have a negative volume impact on the full and transhipped quay wall containers through various South African ports. Thus, the attention points need to be monitored as leading indicators for large-scale shifts that would be found in the detail of subsequent input datasets. The input datasets are, however, lagging in being a recording of historical values, where the attention points are leading indicators that would show a change in the trends of medium-term parameter values to be used in the forecasting horizons. Continued research on these attention points are required to identify shift changes in advance.

Table 9.4: Model verification discussion for Attention points

Req. ID	Model requirement	Marine Deep-sea	Transhipment	Empty
A1	Only palletisable freight should be in containers	This provides an indication of expected percentage containerisation and anomalies that should go through bulk terminals.	N/A	N/A
A2	Port hinterland trade patterns	Change in business factors that encourage containerisation.	Growth or decline in international trade.	N/A
A3	Hinterland economic structure	Change in business factors that encourage increased trade in commodities suitable for containerisation.		N/A
A4	Port competitive position	Development of sub-Saharan African ports will attract full container freight that historically used South African ports. This pattern will influence both marine deep-sea and transhipment model volumes.		N/A
A5	Hinterland states: Investments	N/A	GDP growth in sub-Saharan Africa could increase hinterland consumption and spending in infrastructure projects reducing South African transhipments.	N/A
A6	Port hinterland integration	N/A	Monitor port hinterland integrated development.	N/A
A7	Empty percentage	N/A	N/A	Trends for percentage of full to be monitored for changes.

Req. ID	Model requirement	Marine Deep-sea	Transhipment	Empty
A8	Transhipment percentage	N/A	Trends for percentage of full to be monitored for changes.	N/A
A9	Port capacity and efficiency	Development of competing ports can draw all container volumes away from South African ports. Development of South African ports can attract more volumes to South African ports.		
A10	Container ship size	Change in world ship fleet composition will change containerisation trends and the container ship sizes that operate on shipping routes to and from sub-Saharan Africa.		
A11	Shipping line route decisions	N/A	Development of all sub-Saharan Africa ports will influence shipping lines routing decisions.	N/A
A12	Global shipping fleet	Change in world ship fleet composition will force containerisation if less bulk carriers of certain types are available. Or vice versa.		N/A
A13	Global physical container populations	South African container physical types can only draw from the global physical container types and thus would be influenced by international availability.		
A14	Container unpack position and transport modes	N/A	N/A	Market forces that influence packing/unpacking of containers
A15	Container transhipment factors	N/A	Transhipment concepts were discussed by freight owners that could influence volumes.	N/A

Table 9.5 highlights the verification of three boundary conditions as identified and included in the model. These aspects will need continuous monitoring and could also impact the medium- to long-term forecasts similar to the description above for attention points.

Table 9.5: Model verification discussion for Boundary conditions

Req. ID	Model requirement	Marine Deep-sea	Transhipment	Empty
B1	Weight limits enforced per container physical type	This should be monitored and would provide inputs into ceiling weights per container per container physical type.		N/A
B2	Funding limitations	Limited funding is available for large-scale port expansion projects in sub-Saharan African countries. Changes in funding availability for infrastructure investment projects should be monitored.		
B3	Port regulation and ownership	This aspect needs to be considered as an influencing factor for especially South African ports, but also for sub-Saharan African countries, with many of them having delicate economic and political structures.		

Each of the user requirements, functional requirements, design restrictions, attention points and boundary conditions has been carefully considered and was included in the model design where applicable in one or more of the models. They were all verified as having been included and satisfying the purpose for which they were intended and included in the modelling framework in the first place.

The next step is to validate if the model is doing what it should by comparing the model outputs with actual volumes and alternative forecasting model outputs.

9.3 Model validation: Marine deep-sea

9.3.1 Validation introduction

Validation, as Boehm (1984) defined, is questioning whether the model is doing what it is supposed to do. To perform a complete validation the model needs to be applied to previous data from earlier years to validate that the outputs achieved are indeed accurate and are an improvement to alternative modelling techniques. Due to the complexity of the model, a complete validation of every aspect per port, per commodity, per container physical type, etc., would involve an extensive exercise.

A scenario was built to validate the model based on 2010 container data and by implementing the model to determine a 5-year forecast for 2011 to 2015. The idea was to compare this forecast to a forecast from the same 2010 base year, but using a GDP multiplier. Comparing both of these forecasts with the actual container volumes recorded by TNPA between 2010 and 2015 would provide valuable insight into the accuracy of both approaches.

A few ground rules need to be spelled out to ensure that this comparison is fair:

- The year 2010 will be used as a baseline value for both approaches;
- The comparison will be done for all ports collectively and separately for selected larger ports;
- The comparison will be made for full quay wall containers only (primary objective);
- The same GDP forecast rates were used for the GDP multiplier and the container modelling inputs;
- The GDP multiplier was based on historic container growth vs GDP growth. For these recorded volumes by TNPA for the years 2000–2010 was used as baseline suggesting a port multiplier of 2.0, being on par with GDP multipliers in the range of 2–3 found in the literature referenced in Chapter 3.

It is important to note that both the GDP multiplier forecast and the container model forecast proposed, use the same GDP forecast as underlying input. However, the proposed model uses this on the disaggregated level per commodity and then adds up the containers over all commodities back to a total per port and for the country. Table 9.6 shows the GDP forecast elements used for this validation and the forecast error that is now known from real GDP data (Statistics South Africa, 2017).

Table 9.6: GDP forecast elements used in this validation process

GDP Forecast elements	2011	2012	2013	2014	2015
GDP forecast used in 2010 (Transnet internal project documents)	2.9%	3.4%	4.1%	4.1%	4.1%
Real GDP Growth (Statistics South Africa, 2017)	1.6%	0.3%	2.3%	0.4%	0.5%
Forecast error	-1.3%	-3.0%	-1.7%	-3.7%	-3.6%

With the known GDP growth error between 2011 and 2015 an adjustment can be made for both models to ensure the comparison for both forecasts is done on a fair basis versus the actual container volumes recorded by TNPA over this timeframe. The actual TNPA volumes recorded over this time period are an actual reflection of the real GDP experienced by trade through the ports.

A premise that needs to be accepted is that this time frame was in the wake of the global recession and a difficult time for any forecasting. It can be argued that this had an influence on the accuracy of the forecast, but it is so much more important in these times to have more accurate demand-validated models to predict infrastructure expenditure.

The comparison will first be done for all ports and then focus on the two largest South African container ports, the Port of Durban and the Port of Cape Town. This first part of the validation would thus be a comparative total container view and the second part would be outputs from discussions with users, the TNPA port infrastructure planners.

9.3.2 Container model volume validation – All ports

Figure 9.1 provides the comparative graphs for actual volumes for all South African ports combined. The comparison is between:

- Total GDP forecast: Volumes for all ports based on GDP multiplier forecast;
- Total Model forecast: Volumes from the content-based container modelling process applied to 2010 base year values and input parameter values found in the datasets analysed for this dissertation;
- Total Actual TNPA: The actual volumes over the quay wall as recorded by TNPA.

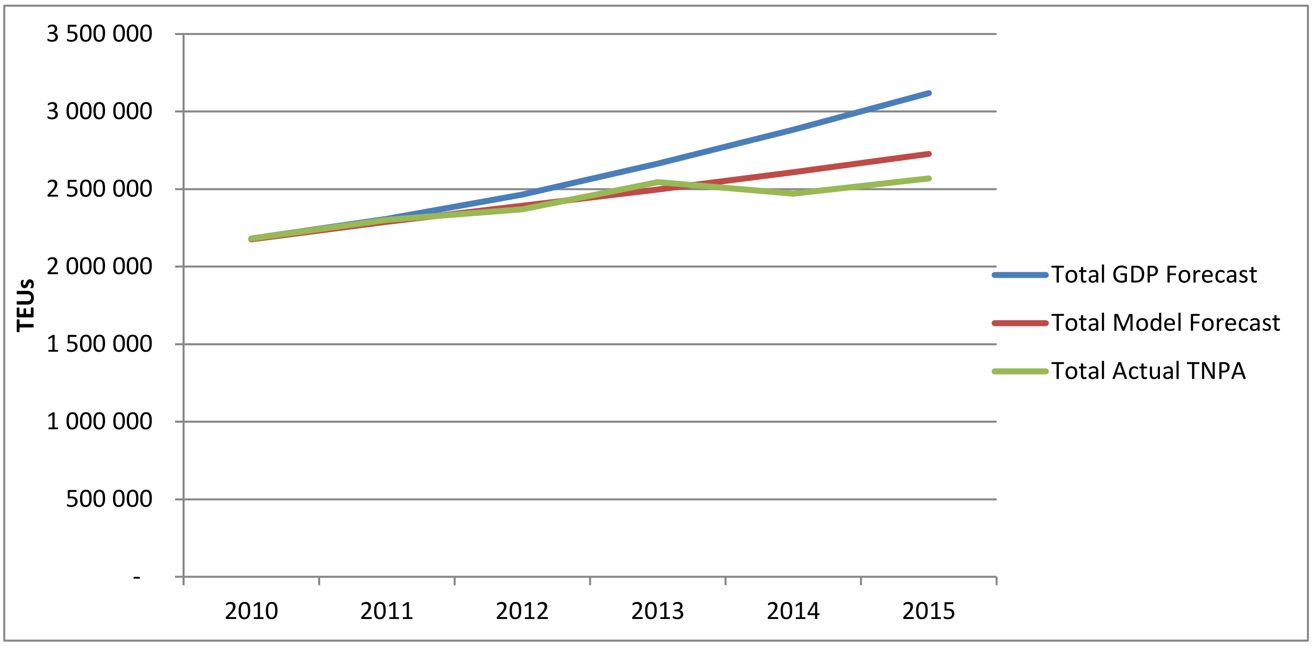


Figure 9.1: Comparison of proposed container model to GDP multiplier forecast and actual volumes

The content-based model was found to predict the container volumes more accurately, even though it was not 100% accurate. Figure 9.2 shows that the proposed content-based model's error remained within 7% of the actual recorded volumes over the five-year forecast. The GDP multiplier overstated capacity by more than 20% on the same five-year horizon. Over the longer term (30-year forecast) this error would become even larger. The five-year horizon is the time frame within which large-scale port infrastructure projects are usually initiated and executed, and is thus a sufficient timescale to compare on at this stage.

The GDP forecast error was also included in Figure 9.2, indicating that the proposed model from this dissertation's forecast would be even closer to the actual TNPA volumes recorded if this forecast error were to be removed from both forecast volumes.

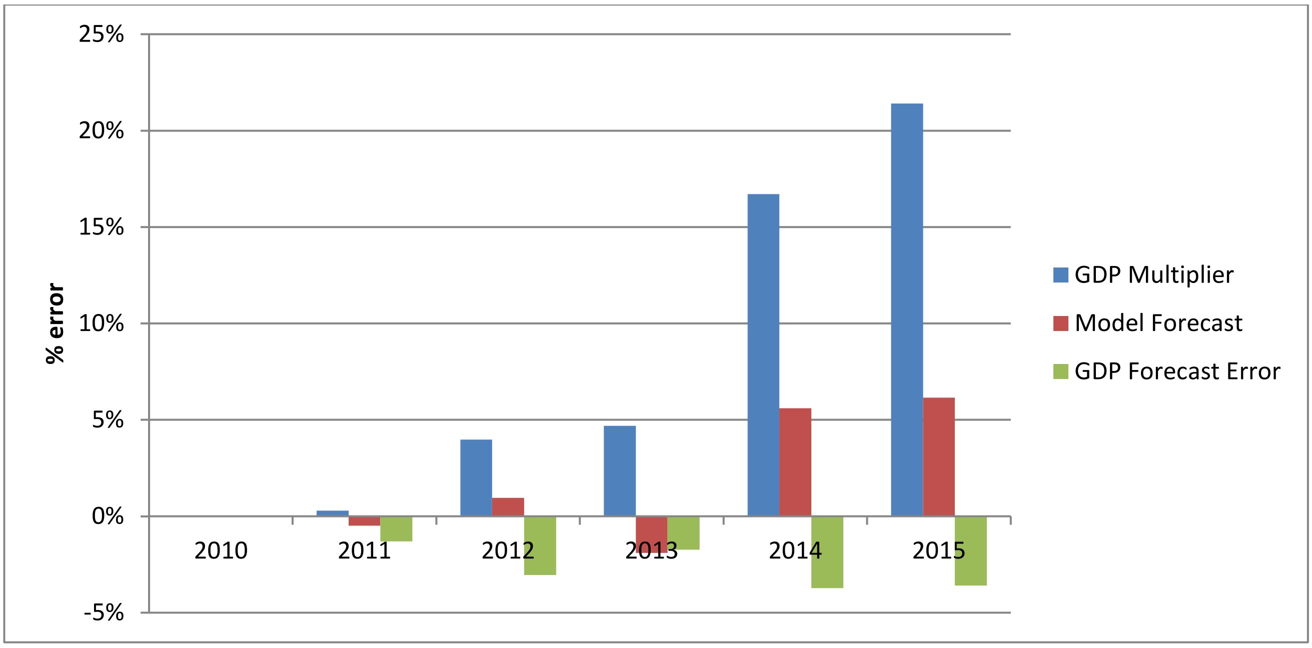


Figure 9.2: Annual comparative forecast error over the five-year horizon (with GDP forecast error)

Figure 9.1 is repeated as Figure 9.3 with an adjustment made for the forecast error as calculated in Table 9.6 and shown in Figure 9.2. It can be seen that in this case the proposed model follows a much closer pattern to the actual TNPA container volumes. In all subsequent figures the forecast error was adjusted to show a more accurate reflection of the actual versus forecast volumes.

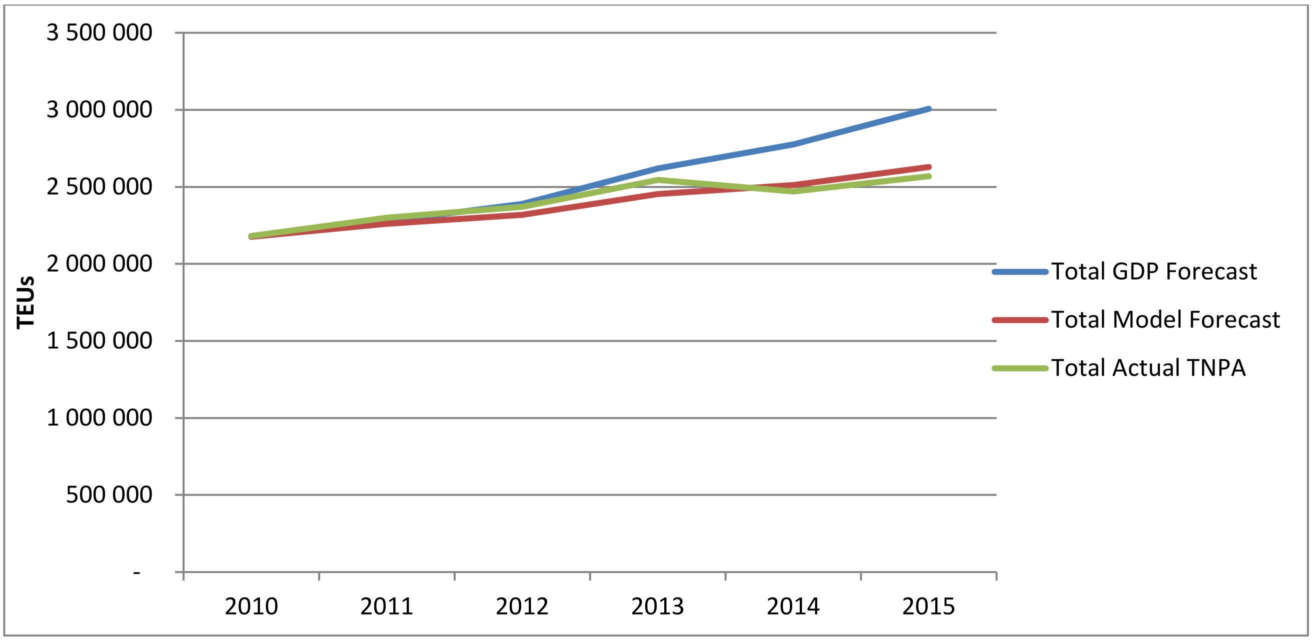


Figure 9.3: Comparison of proposed container model to GDP multiplier forecast and actual volumes (corrected for GDP forecast error)

In Figure 9.4 it shows that the proposed model had a forecast of 1.8% to 3.6% below the actual volumes between 2011 and 2013. Since these forecasts should drive capacity increases, it would be a concern whenever the actual volumes are found to be more than the forecasts, indicating a potential unforeseen demand and subsequent late commissioning of new capacity. Thus, it might create some concern that in the earlier years up to 2013 the proposed model forecast was lower than the actual TNPA volumes recorded. On the other end of the spectrum, the overstated forecasts between 2013 and 2015 by 2.9% to 17% proposed by the GDP multiplier method seem problematic, requiring additional capacity that was not required at all. In order to understand this, a more detailed analysis of these differences per port and also for import and export separately might be helpful to understand the benefits and disadvantages of both approaches. Port planners should consider the details and the risk associated with a too low forecast when deciding on the final port volumes they need to provide for.

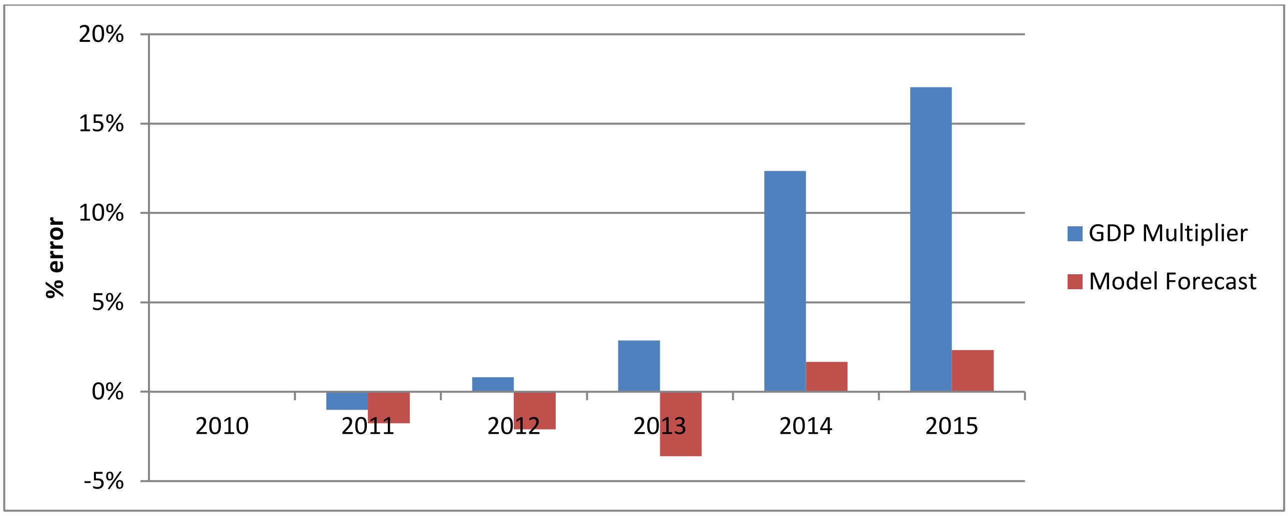


Figure 9.4: Annual comparative forecast error over the five-year horizon (corrected for forecast error)

To illustrate this, similar comparisons were made for all South African port volumes combined, but for the export and import volumes separately, shown in Figure 9.5 and Figure 9.6 respectively. From these two graphs can be seen that the GDP multiplier error for imports were smaller than the GDP multiplier error for export volumes. One could argue that the errors shown are typical of an economy that has been struggling to perform as shown in the GDP forecast errors in Table 9.6. The South African economy has not been able to achieve its growth targets due to a lack of manufacturing growth. Due to this, exports are showing much lower actual volumes than predicted, where the import volumes were higher to substitute for this lack of local manufacturing growth.

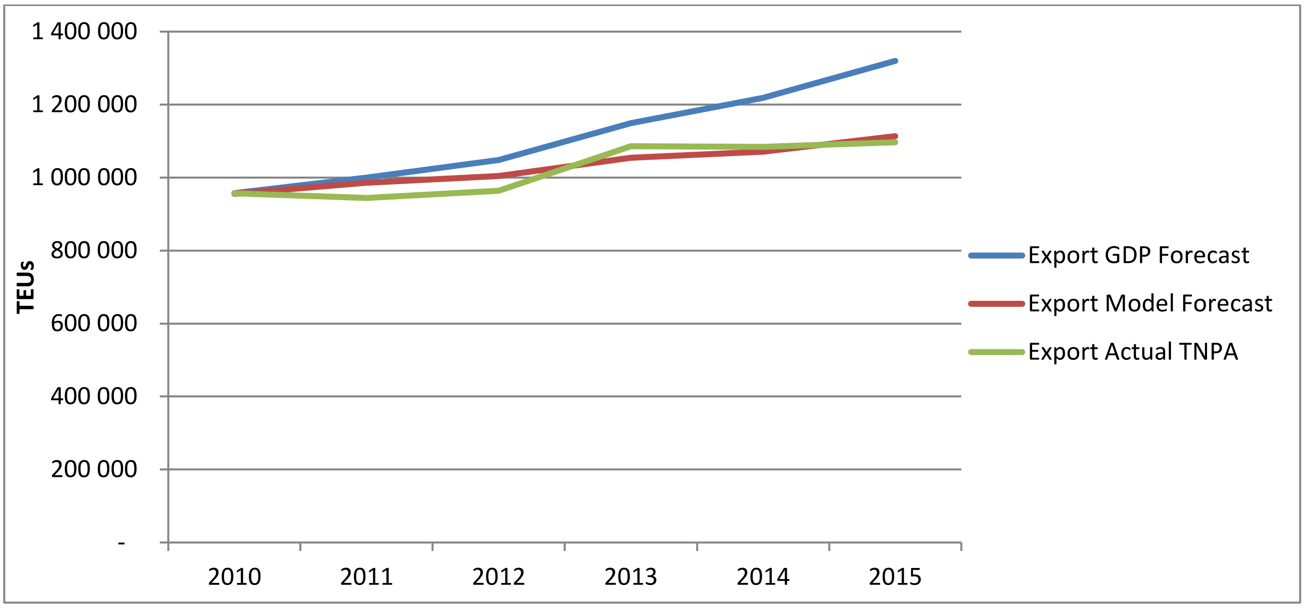


Figure 9.5: Comparison of export volumes for proposed container model to GDP multiplier forecast and actual volumes

In both instances the content-based quay wall container forecasting model provides a more accurate view of what actually happened, especially towards the end of the five-year forecast horizon. In 2015, the export error is 1.5% and the import error 2.9% for the proposed model, while the GDP multiplier method shows errors of 20.3% and 14.6% respectively. Viewing the imports and exports separately helps one to understand the economic significance of the forecasts and to explain the differences; however, it does not add value from a port capacity perspective other than highlighting a directional imbalance. In the end port planners need to plan for combined volumes in both directions.

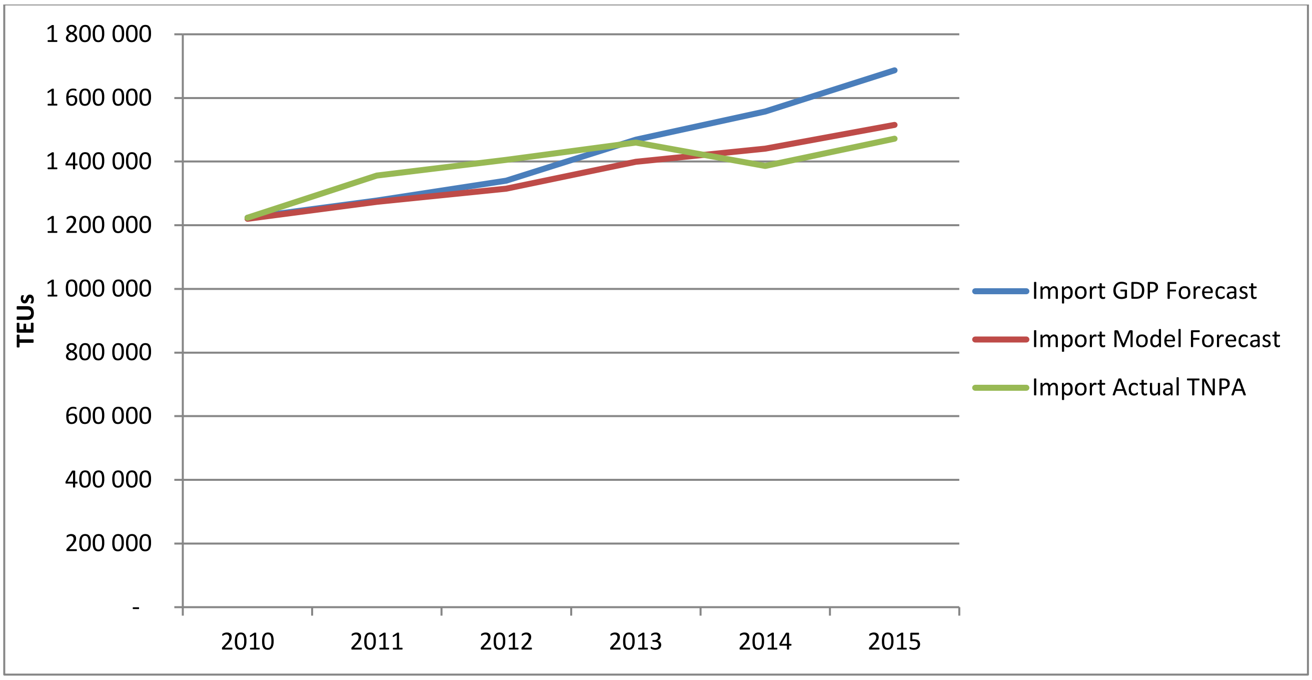


Figure 9.6: Comparison of import volumes for proposed container model to GDP multiplier forecast and actual volumes

Numerous other result illustrations can be drafted to labour this point further, e.g. per port, per commodity, or per physical container type. Unfortunately, the TNPA actual data recorded does not have actual data on most of these dimensions, thus providing no means of comparing the proposed model's generated values with actual volumes. The following two sections briefly look at the port forecast comparisons for South Africa's two most significant container ports, i.e. the Ports of Durban and Cape Town.

To illustrate some of the numerous other views that can be done, a number of result graphs are displayed in section 9.4. These graphs originate from the application of the content-based container forecasts as applied to the 2013 base year data. The purpose of these illustrations would be to explain the typical aggregated outputs that can be used by port planners to argue their case for expansion projects from the position of a content-based validated demand forecast. But first a number of port validation comparisons and arguments are done for the Ports of Durban and Cape Town.

9.3.3 Container model volume validation – The Port of Durban

To do the validation for a specific port like Durban it is important to establish some more ground rules. This validation focuses on the full quay wall container and to illustrate the requirements for new container capacity over the 2010 to 2015 validation period, the Port of Durban capacity and percentages for empty and transhipments are applied to full container numbers.

Some of the input data used in this validation, are:

- Durban port capacity in 2010 was 2.8 million TEUs (Transnet internal project documentation);
- Durban empty containers landed in 2010 was 5.9% of full containers (TNPA, 2017);
- Durban empty containers shipped in 2010 was 17.4% of full containers (TNPA, 2017);
- Durban transhipment containers shipped and landed in 2010 was 12.8% of full containers (TNPA, 2017);
- Due to the baseline being 2010, the known empty and transhipment percentages since 2010 are ignored for this calculation;
- The known GDP error is ignored for this first illustration.

The above input data can be combined with any forecast to determine the full port capacity by adding transhipment and empty containers to the forecast of full containers per annum. These methods were applied to obtain the total container volumes for the Port of Durban as shown in Figure 9.7. This compares the GDP multiplier, the content-based forecast models, the actual TNPA volumes recorded, and the Port of Durban's capacity as at 2010. This graph shows that the GDP multiplier method would indicate an infrastructure capacity expansion for the Port of Durban about two years earlier than what the content-based model recommends.

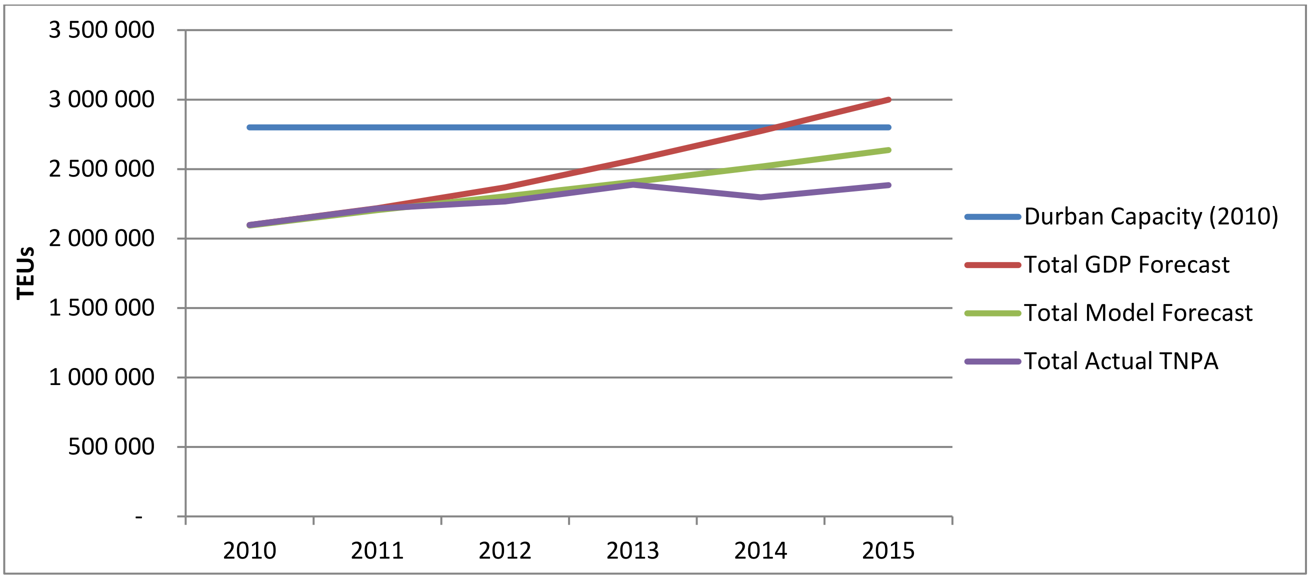


Figure 9.7: Comparing total container throughput forecasts for the Port of Durban against capacity (including empty and transhipment volumes)

Earlier in Chapter 3 the Durban dig-out port expansion was mentioned. Online news articles mentioned rough figures for the dig-out expansion of up to R100 billion. If one assumes a 10% return on investment requirement by Transnet, this equates to R10 billion loss of income for every year that it is built too early. On the other hand, if it is built too late, it equates to holding back the South African economy and slowing much-needed GDP growth. Eskom numbers often mentioned in news articles equate to a 0.4% GDP growth decline (Sharp, 2015), and thus building port capacity too late could be costing South Africa about R4.2 billion per annum (Statistics South Africa, 2017). Where the income loss is once-off, the GDP growth loss will probably never be recovered.

A second validation point to ponder would be to incorporate the known GDP error highlighted earlier and adjust container volumes to then compare the accuracy of the two forecast methods for the Port of Durban volumes. A further set of validation calculations was done for full quay wall containers only. The volumes were adjusted for the actual GDP forecast error noted in Table 9.6. The output container volumes for full quay wall containers as forecast by the two methods and compared to TNPA actual volumes are shown in Figure 9.8.

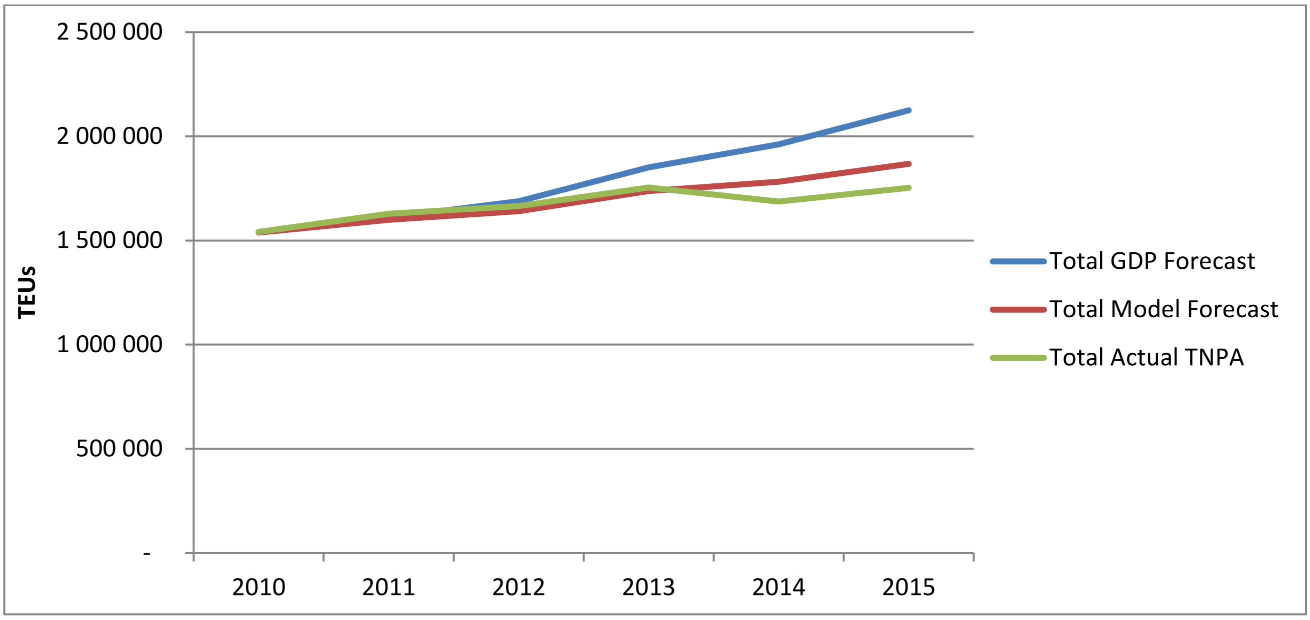


Figure 9.8: The Port of Durban – Comparison of proposed container model to GDP multiplier forecast and actual volumes)

The content-based model shows a very similar pattern to the actual volumes for the time period from 2010 to 2013 with much lower than expected volumes recorded for 2014 and 2015. The GDP multiplier method indicated much higher volumes than the actual TNPA volumes from 2013 to 2015. Figure 9.9 indicates that the content-based model showed (corrected for GDP error) a demand forecasting error of 6.6% above the actual volumes experienced over the five years. Over the same time period the GDP multiplier forecast proposed a 21.2% overshoot of capacity at the end of the five-year period.

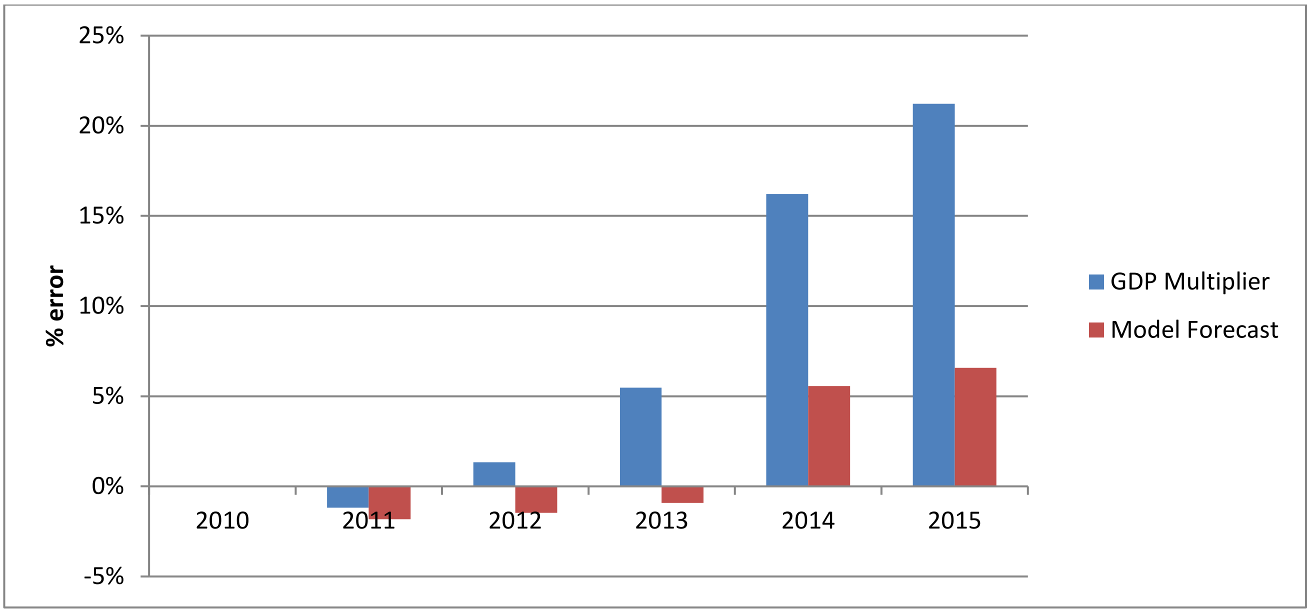


Figure 9.9: The Port of Durban –Comparative forecast error (corrected for GDP error)

9.3.4 Container model volume validation – The Port of Cape Town

A similar unadjusted calculation for the Port of Cape Town was done to establish when the different forecast methods would overshoot this port's capacity. Some of the input data specific to the Port of Cape Town used in this validation, are:

- Port capacity in 2010 was 0.8 million TEU's (Transnet internal project documentation);
- Empty containers landed in 2010 was 14.8% of full containers (TNPA, 2017);
- Empty containers shipped in 2010 was 15.7% of full containers (TNPA, 2017);
- Transhipment containers shipped and landed in 2010 was 9.1% of full containers (TNPA, 2017);
- Due to the baseline being 2010, the known empty and transhipment percentages since 2010 are ignored for this calculation;
- The known GDP error is ignored for this first illustration.

These methods were applied to obtain the total container volumes for the Port of Cape Town as shown in Figure 9.10. This compares volumes from GDP multiplier, the content-based forecast model, the actual TNPA volumes recorded, and the Port of Cape Town's capacity as at 2010. This graph shows that the GDP multiplier method would indicate an infrastructure capacity expansion for the Port of Cape Town approximately one to two years earlier than the content-based model recommends.

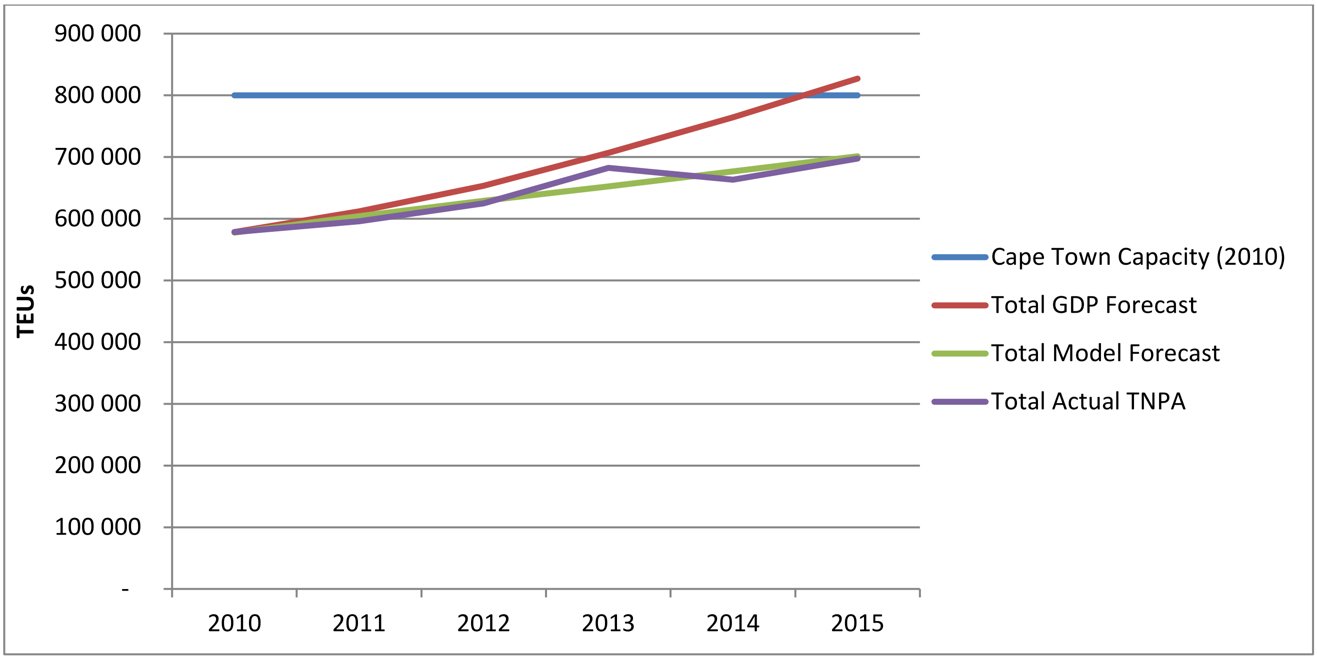


Figure 9.10: Comparing total container throughput forecasts for the Port of Cape Town against capacity (including empty and transhipment volumes)

A second validation point to ponder would be to incorporate the known GDP error highlighted earlier and adjust container volumes to then compare the accuracy of the two forecast methods for the Port of Cape Town volumes. A further set of validation calculations was done for full quay wall containers only. The volumes were adjusted for the actual GDP forecast error noted in Table 9.6. The output container volumes for full quay wall containers as forecast by the two methods and compared to TNPA actual volumes are shown in Figure 9.11.

Based on the container content made available through the shipping line sample data, 2013 was an exceptional year for imports at the Port of Cape Town. This included significant volume growth in processed foods from Europe and South America, manufactured products from Europe and metal products also from

Europe. The Port of Cape Town also had significant export growth with better than usual containerised wine exports to markets across the world and a very good deciduous fruit season with higher than usual fruit exports to Europe.

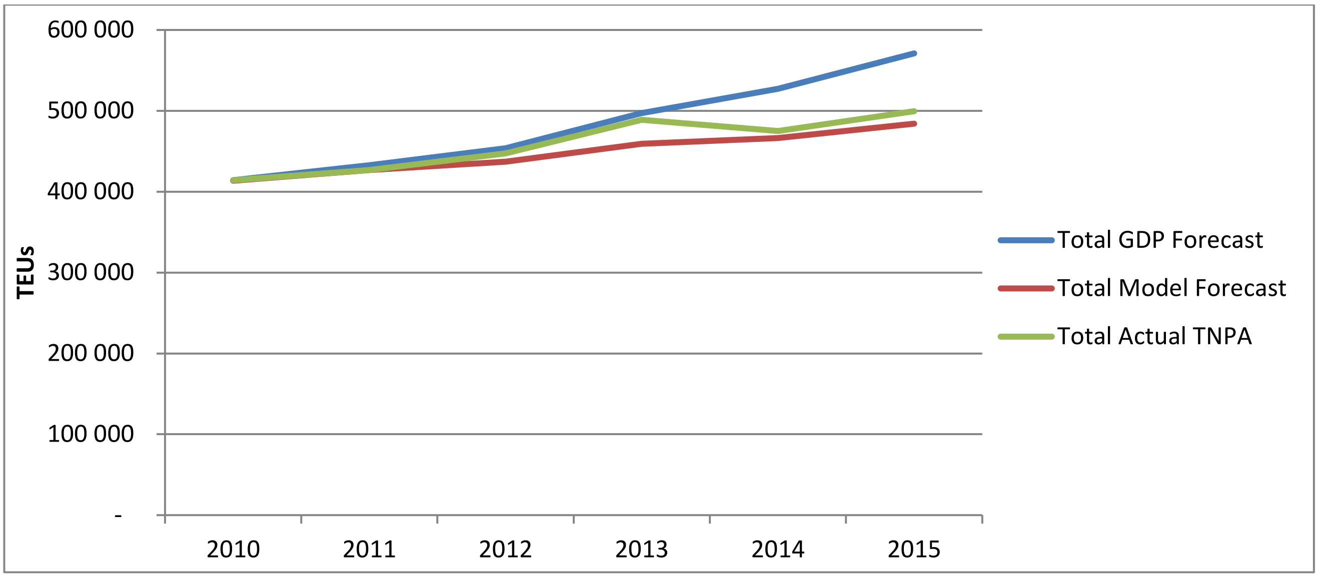


Figure 9.11: The Port of Cape Town – Comparison of proposed container model to GDP multiplier forecast and actual volumes

The figure shows this actual growth was higher than forecasted growth, and indicates that some additional capacity would be required for ports that are used especially for agricultural products with volumes that can fluctuate due to unknown seasonal patterns. Figure 9.12 shows this error for the proposed model being as high as 6.1% below the actual volumes, emphasising the importance of having buffer capacity with agricultural volumes at certain ports. The GDP multiplier forecast again shows a high forecast error towards the end of the five-year horizon reaching 11.0% and 14.3% in 2014 and 2015 respectively. Port planners need to review the composition of port container contents to ensure that the port capacity is sufficient to cater for the specific variability found in especially seasonal agricultural produce. A validated demand forecast would assist port planners to plan for these fluctuations based on content, and not on gut feel or historic unknown patterns.

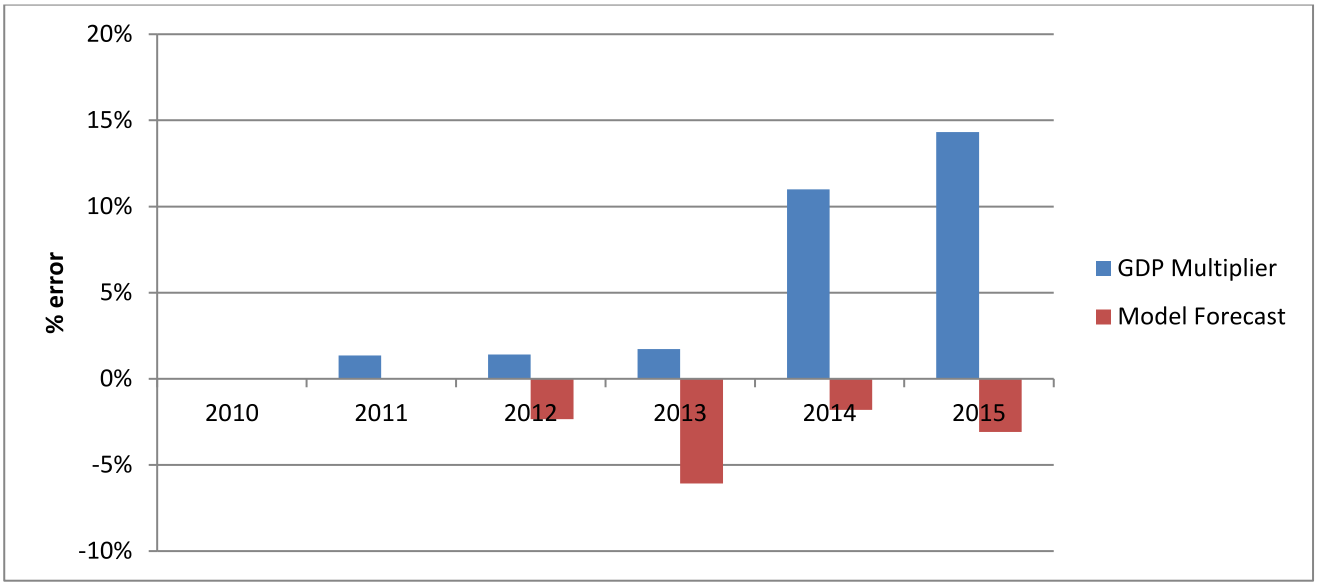


Figure 9.12: The Port of Cape Town – Comparative forecast error (corrected for GDP error)

Similar validation exercises can be done for the smaller container ports, however, the next ranked ports in line for comparison are the combined Ports of Ngqura and Port Elizabeth. With the dynamics introduced with the fairly newly built Port of Ngqura and volumes still changing rapidly from a very low base, the author felt it would be difficult to isolate out this effect, and thus decided to exclude this port combination from further validation exercises. The other container ports contribute in the region of 2% or less to the total container volumes and will not contribute any value to further discussion.

9.3.5 Container model user validation

As part of the model validation a follow-up meeting was held with the Transnet Port planning team to discuss their objective opinion and concerns over the results and outputs generated by the container model segments. Their feedback can be summarised as follows:

- They are mostly positive about the methodology followed to determine the modelling parameters and input values for these parameters.
- They agree with the influencers for these parameter values.
- They are concerned about the complexity of some of the modelling segment's aspects and the effort and challenge involved to continuously populate these input parameters with updated values
- They do however understand the trade-off between complexity of inputs and accuracy of outputs and appreciate that some level of complexity needs to be tolerated.
- One of their major concerns is the depth of knowledge they require on container physical types and the lack of depth in the input values obtained and the resultant lack of confidence in the output detail of container types. They are satisfied with the framework created and appreciate that Transnet divisions can play a significant role in increasing the understanding by capturing more container physical type detail.
- The pack/unpack phenomenon and how it was modelled for the domestic hinterland transport leg of imports and exports is a concern from their TFR planning perspective, but details fall outside the scope of this dissertation. In short, more work is required.

Other aspects in terms of model validation are that the feedback obtained from the survey and focus groups merely strengthened the modelling parameters already derived from literature and analysing the shipping line and industry datasets. Thus, no new parameters were introduced through this primary research effort in Chapter 6. However, the focus group participants confirmed and accepted the tabled modelling framework and provided valuable inputs into more-detailed values for the input parameters.

9.3.6 Model validation conclusion

The input values prove to be crucial. Some level of sensitivity analysis was done during the analysis to determine the highest influence factors to invest more time and effort into obtaining higher confidence in these specific input values. The sensitivity is at two levels. One aspect is the sensitivity towards total quay wall containers where full traded containers are the most significant volume contributor. Empty export containers prove to contribute significant volumes to some ports, especially the Port of Durban while transhipment containers (full and empty) also contribute significantly towards the Ports of Durban and Ngqura. The focus should thus be on obtaining accurate input parameters for these high-volume contribution modelling segments for these ports specifically.

The next level of sensitivity analysis was done on dominant containerised commodities like fruit exports in reefer containers through the Port of Cape Town, and some other commodity port combinations. These contribute significant volumes and effort was invested in finding additional data sources like industry databases and the PPCEB volumes to increase the accuracy of these modelled volumes as indicated in section 5.4.6 for citrus exports.

Agricultural commodities will always provide some short-term level of uncertainty and error due to the link to weather patterns experienced by this sector in each season. Short-term adjustments might be required to compensate for seasonal changes in production volumes, but long-term infrastructure capacity plans can be based on forecasts and investments reported by agricultural industry groups and economists.

Continuous improvement projects to better understand input values are crucial, but the quay wall content-based modelling framework and parameters proposed in this dissertation can be fixed for the medium term.

9.4 Container modelling illustrative forecasting results

9.4.1 Marine deep-sea container movements

Figure 9.13 shows the total TEUs forecast in the low, likely and high scenarios for both exports and imports. (Note the split axis between the forecast years for 2019, 2024, 2029, and 2043 for many of the graphs in this section.) Due to South Africa’s increasing demand for manufactured and consumer goods, imports are expected to grow much quicker than exports.

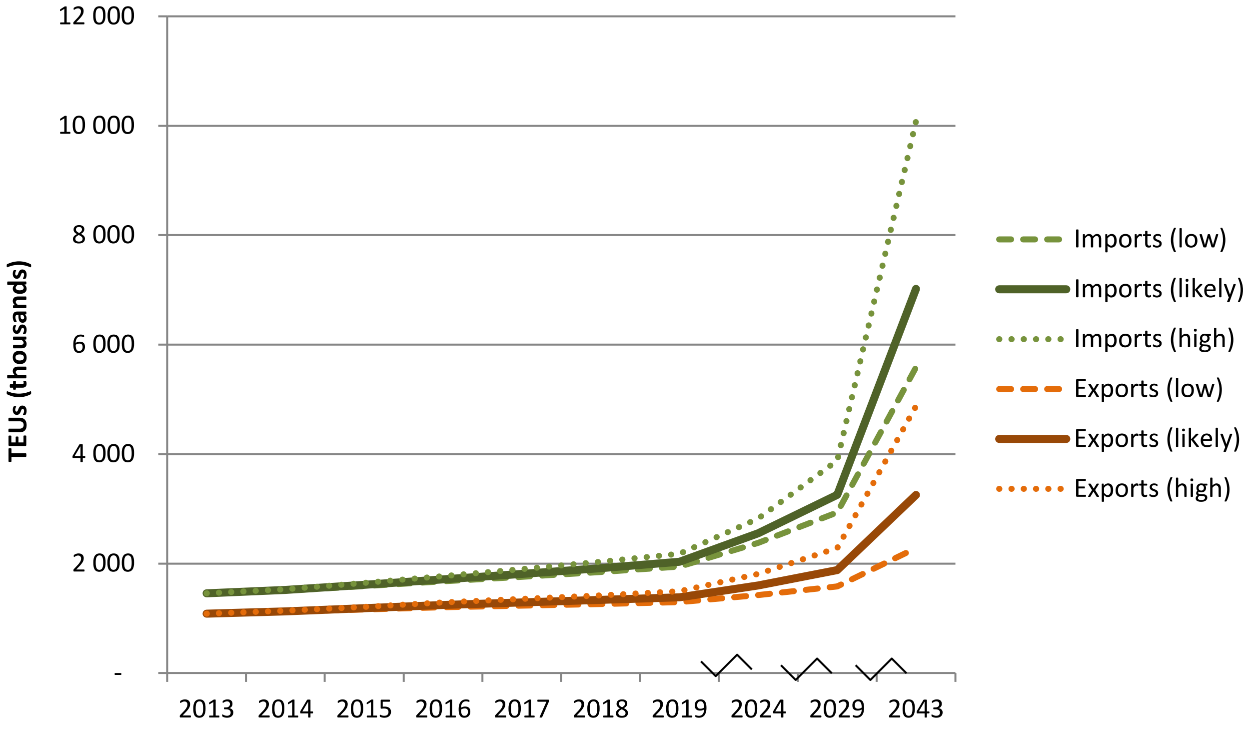


Figure 9.13: Total TEU forecast for marine deep-sea container movements

Figure 9.14 shows the proportional split in container types for imports and exports. Forty-foot containers are expected to continue dominating the physical types as the global trend is to move towards forty foot containers and away from twenty foot containers (Refer to sections 4.3.3 and 6.3.4 for literature and focus group aspects on these views). High cube containers are becoming more prominent, especially for lighter commodities that can fill a normal forty foot in terms of volume long before it has reached its maximum weight.

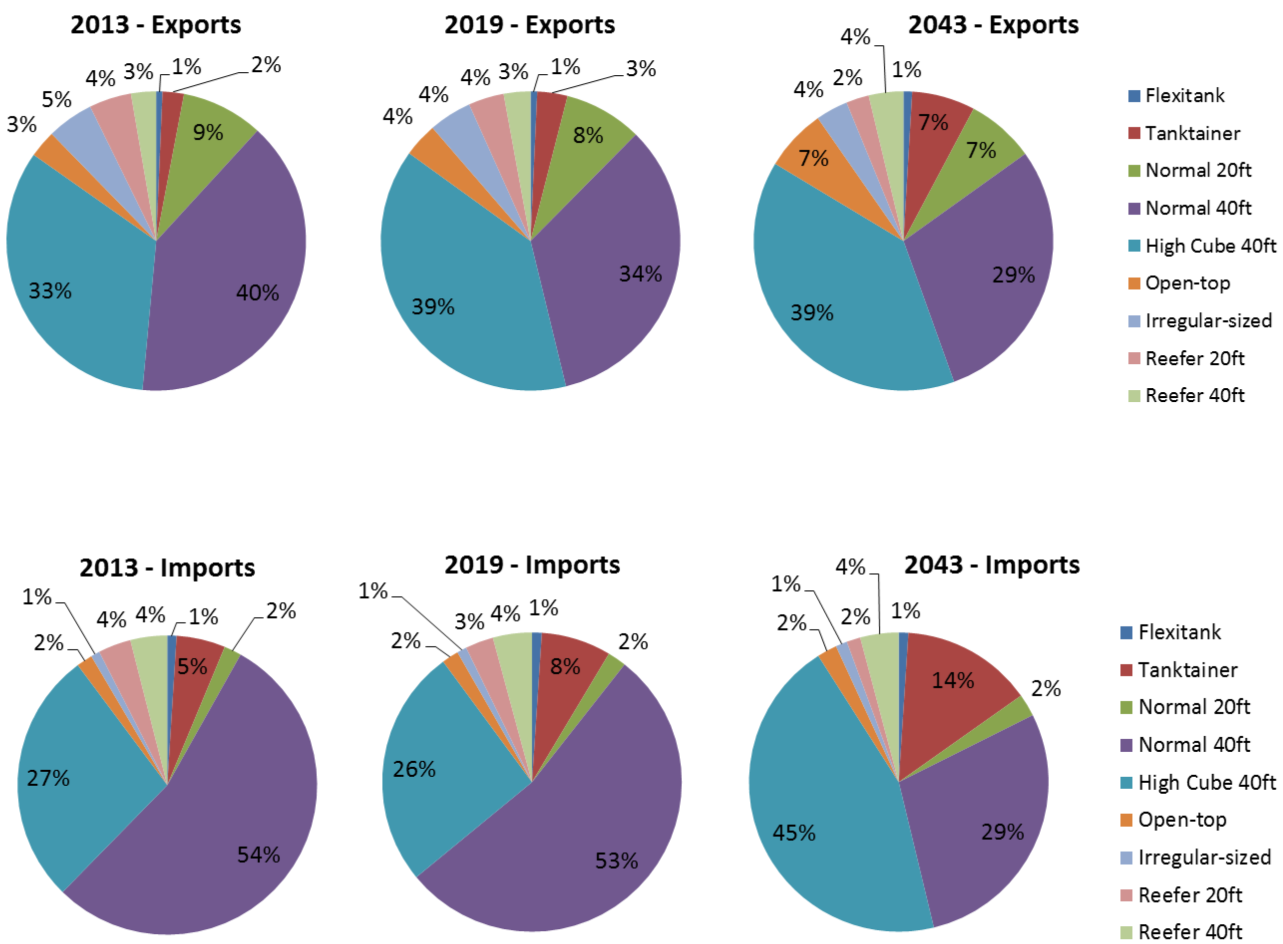


Figure 9.14: Container type split for imports and exports

Figure 9.15 and Figure 9.16 show the total import and export volumes per port respectively from the content-based model. These figures show the overall dominance expected by the Port of Durban in both imports and exports.

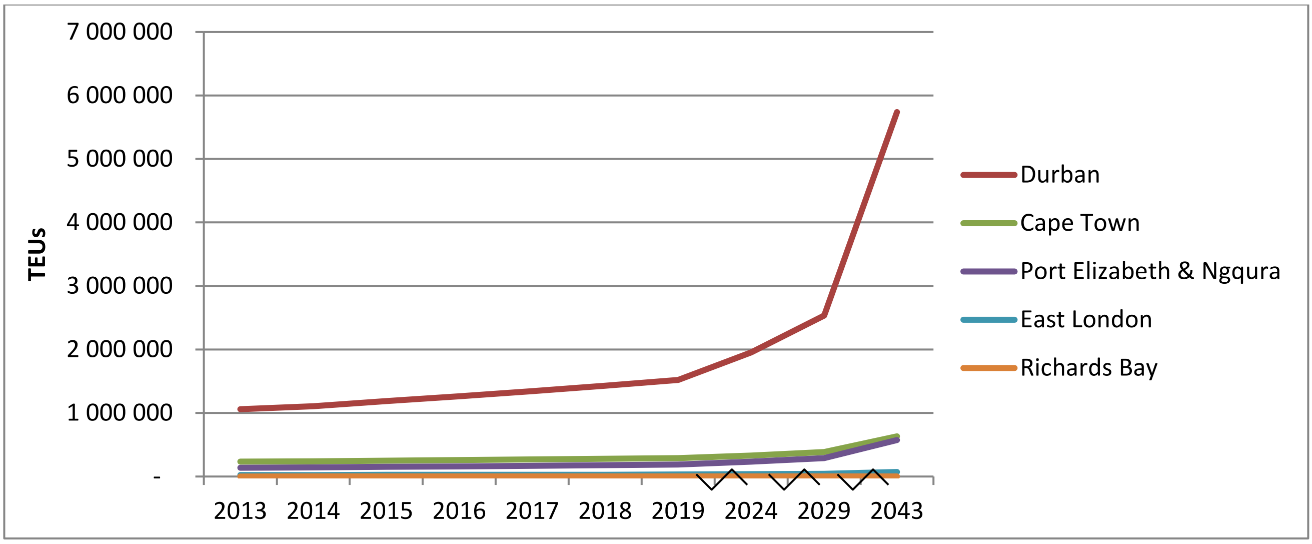


Figure 9.15: Forecast container import volumes per port

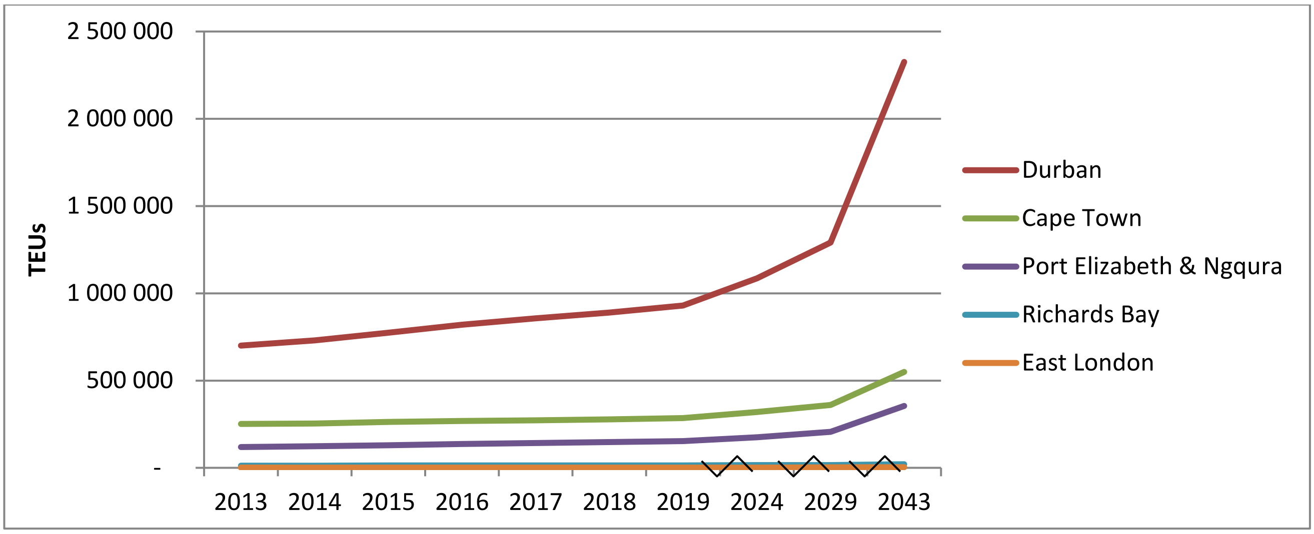


Figure 9.16: Forecast container export volumes per port

These figures also highlight the continued disconnect between import and export volumes into the future, leading to a massive continued export of empty containers, mostly from Durban, to be returned to our trade partners. South African trade is so small compared with world volumes that only one dominant port in South Africa will prevail far into the future unless drastic structural economic incentives are provided or policies put in place to enforce a massive shift in economic activity away from the Gauteng-Durban hinterland port integration.

The combined volumes from Figure 9.15 and Figure 9.16 put South Africa at a total of over 10 million TEU and Durban at over 8 million TEU by 2043. Transnet internal project documentation dated 2010 put the current Port of Durban capacity limit at 4.8 million TEU, making the proposed dig-out expansion to the old airport site imminent according to the content-based model by 2027, if similar guidelines for empty and transhipment volumes are included as discussed in section 9.3.3. The same Transnet internal documentation from 2010 predicted a 12 million TEU demand by 2042 (including empty and transhipment volumes) and reaching the current Port of Durban capacity limit by 2022, thus five years earlier. The content-based forecast predicts 10.5 million TEU by 2042 (including empty and transhipment volumes).

These differences highlight the importance of accurate validated demand in order to plan accurate timing of container port expansion projects.

9.4.2 Deep-sea empty container movements

It is only when one considers how many containers had to be imported and exported to restore the balance that the anticipated magnitude of the mismatch is appreciated. Figure 9.17 shows that under the current model assumptions, deep-sea exports are expected to rise rapidly over the long term, while imports show only moderate growth. The underlying reason for this is the excessive supply of normal forty foot containers in the hinterland. South Africa will import increasingly more manufactured and consumer goods, but the export of similar goods (using similar containers) is not expected to grow at the same rate. The other factor that causes this growth in exports is the business policies that stipulate that empty containers be immediately taken back from the hinterland to depots near the port. Many of these containers are then exported by the shipping lines for use elsewhere in their global fleet.

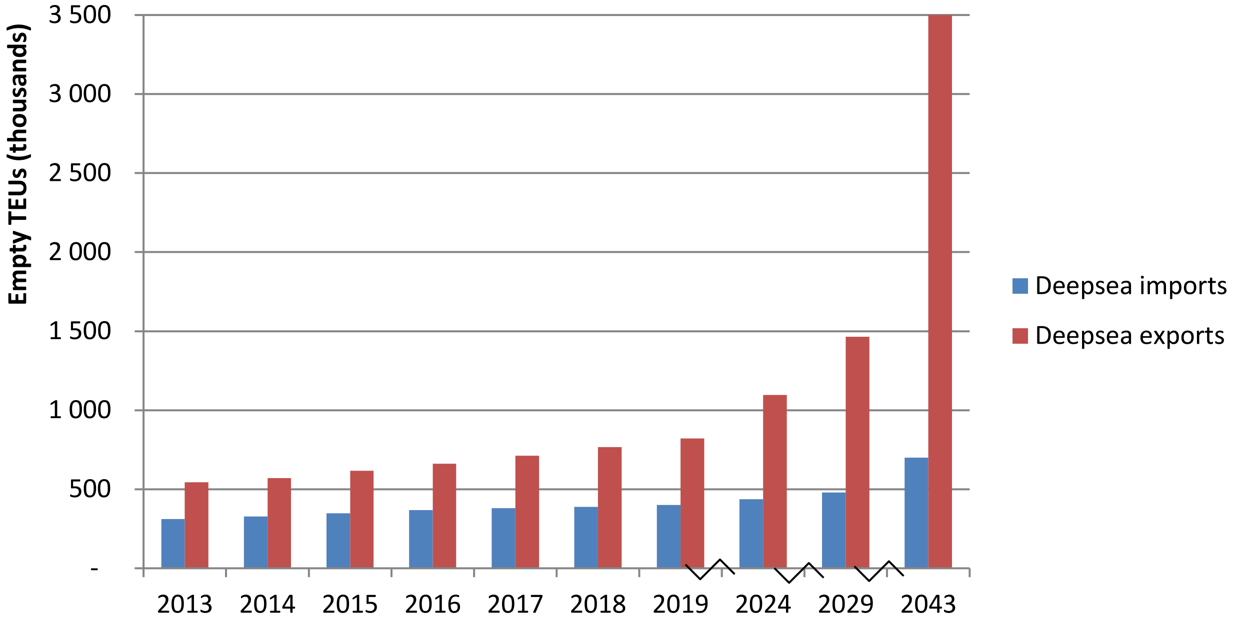


Figure 9.17: Marine-based empty repositioning

9.4.3 Transhipped container movements

To determine the potential market for natural transhipments, imports and exports to Angola, Congo, the Democratic Republic of the Congo (DRC), Kenya, Mozambique, Namibia and Tanzania over the next 30 years were considered, using data from the Regional Freight Demand Model. For each country, it was determined on a commodity-by-commodity basis how many tonnes would be containerised. As a starting point, the containerisation propensities used in the Marine Coastal and Domestic Intermodal subcomponents are applied, but these propensities can easily be updated.

To translate the containerised tonnes into a number of containers per commodity per country, the weight parameters used for the Marine Coastal and Domestic Intermodal are applied. A differentiation is also made between twenty foot and forty foot containers. The result is that for each country, for each commodity, there is a forecast of the number of containers that would be imported or exported via deep-sea shipping.

A last step in determining the potential market would be to determine whether the number of containers falls within the transhipment range – i.e. parcel sizes are still small enough to require consolidation, but also big enough to allow for containerisation. Defining the potential market in this way it would seem that the market will stay rather stable over the next 30 years as shown in Figure 9.18.

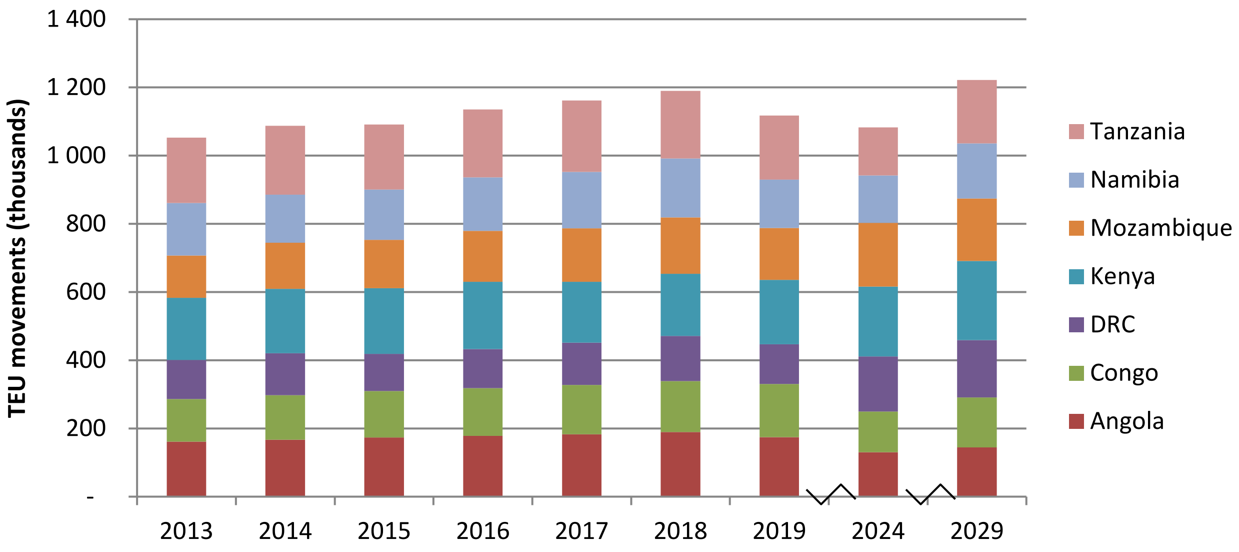


Figure 9.18: Potential natural transhipment market in terms of TEU movements

The degree to which South African ports will capture these natural transhipment containers depends firstly, on the capacity and capability of other African countries to handle direct shipments. Secondly, it depends on the competitiveness of South Africa's port system, although for natural transhipments this is a lesser concern than for strategic transhipments. Three scenarios were modelled for natural transhipments:

Extrapolated growth: Over the past decade, natural shipments have constituted, on average, 20% of the total number of TEUs handled at the ports. This scenario assumes a business-as-usual perspective where natural transhipments remain 20% of this total.

Decaying growth: Current port developments in Africa threaten the natural transhipment market for South Africa. This scenario assumes that African ports become increasingly more capable and efficient in handling direct shipments. Furthermore, intense competition from regional ports may even see transhipments shifting away from South Africa completely.

Competitive growth: This scenario assumes that South Africa becomes an even more competitive option for natural transhipments to the region and that increasing capacity is available for transhipments. Table 9.7 lists the percentages associated with each scenario and Figure 9.19 displays the growth bands over the 30-year period. It is interesting to note that the limited potential market is expected to constrain growth in the long term as African ports develop further and volumes grow sufficiently to allow for direct shipments.

Table 9.7: Natural transhipments as a percentage of total port TEUs for each scenario

SCENARIO	2013	2019	2043
Extrapolated growth	20%	20%	20%
Competitive growth	20%	22%	26%
Decaying growth	20%	14%	10%

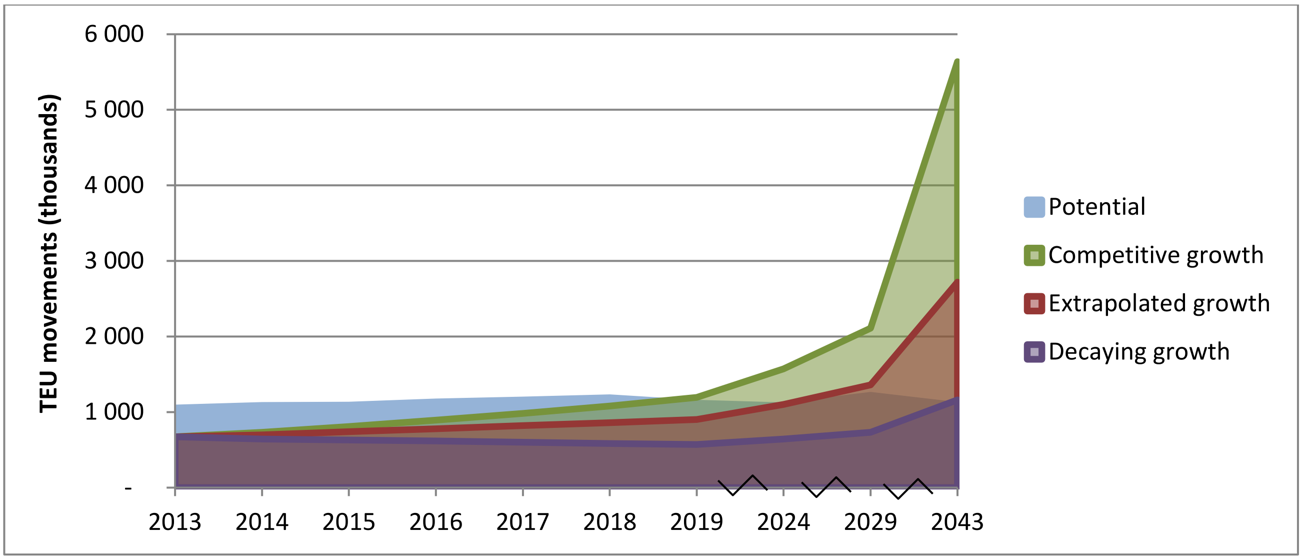


Figure 9.19: Natural transhipment growth compared to the potential market

The potential market for strategic transhipments is difficult to define based on global trade. Rather an approach is used that considers the number of additional vessels that could be serviced in a year. The potential market depends greatly on shipping line decisions. The design of shipping routes and the increasing size of container vessels are but two factors that could either disqualify South Africa or make it a viable competitor.

The same three scenarios are defined for strategic transhipments:

Extrapolated growth: Since the commissioning of the Port of Ngqura and a deliberate strategy to attract strategic transhipments, strategic transhipments have constituted approximately 4% of the number of TEUs handled at ports. This scenario assumes a business-as-usual perspective where strategic transhipments remain 4% of this total.

Decaying growth: This scenario basically considers South Africa losing out to a more competitive transhipment port in the region or shipping lines reconfiguring their routes and increasing vessel sizes to such a degree that South Africa is no longer a viable option.

Competitive growth: This scenario assumes that South Africa is successful in establishing one or more transhipment hubs that can be globally competitive in terms of cost and time efficiencies. Given the volatility of the market, the concept of the feasibility of dedicated capacity for strategic transhipment is still widely debated.

Table 9.8 lists the percentages associated with each scenario and Figure 9.20 displays the growth bands over the 30 year period. Once again it is shown that ambitions to increase South Africa's share of strategic transhipments will require significant additional capacity in the port system.

Table 9.8: Strategic transhipments as a percentage of total port TEUs for each scenario

SCENARIO	2013	2019	2043
Extrapolated growth	20%	20%	20%
Competitive growth	20%	22%	26%
Decaying growth	20%	14%	10%

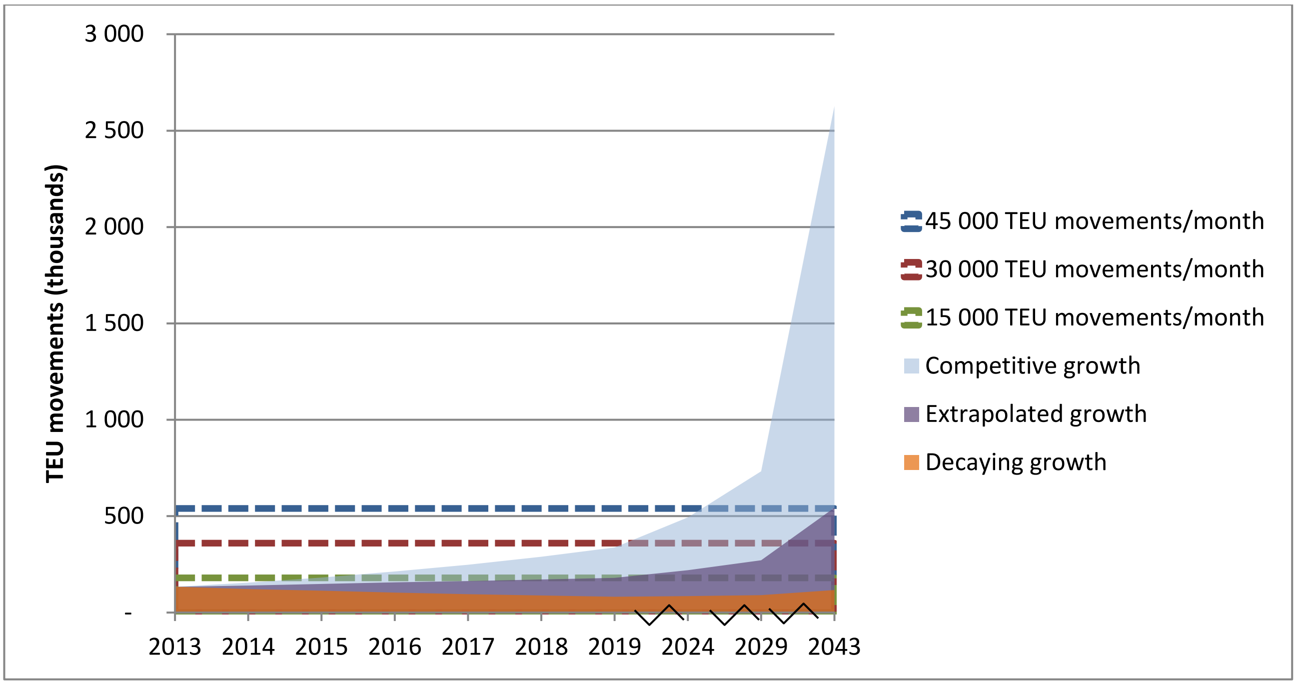


Figure 9.20: Strategic transhipment growth compared to the potential market

The results are indicative of the outcomes that could be achieved with the vast amount of information generated by the container model segments proposed in this dissertation. A complete overview of this is not possible within this context.

9.5 Conclusion

This chapter focused on verification and validation of the developed model for full quay wall containers proposed in Chapter 8. The design requirements were reviewed to ensure that all the proposed design requirements from Chapter 7 had been included and that the model does in fact adhere to the research inputs and user requirements identified.

To validate the model, a scenario was built where the actual South African container volumes recorded by TNPA between 2010 and 2015 were compared to a GDP multiplier forecast and the outputs generated by the developed content-based container forecasting model. The content-based model proved to be more accurate at a total port, import and export level than the GDP multiplier often used in forecasting techniques found in Chapter 3.

Finally, some illustrative results from the various modelling segments was shown and discussed to provide the reader with an overview of the type of aggregated outputs available to port infrastructure planners.

10. Conclusions

10.1 Introduction

This final chapter of the dissertation provides feedback on how well the proposed methodology was followed and the successes achieved in analysing the container content data made available by shipping lines. The outcomes are briefly discussed to highlight the achievements and what potential there is for port infrastructure planners to incorporate these achievements into their full quay wall container flow forecasts.

This chapter also highlights the unique contribution made by the author to this study field on quay wall container forecasting and how this new knowledge would enhance the research in this field.

Finally some recommendations are made regarding further research topics. A few suggestions are also made on how the outcomes should be applied in the field of container modelling based on content knowledge. A few recommendations are also made to industry in how to capture container content knowledge and other influencers that would increase the accuracy of future content-based quay wall container forecasts.

10.2 Methodology overview

A basic systems engineering approach was followed to guide the development of the container forecasting model as shown in Figure 10.1. The research was an empirical study utilising both secondary quantitative data analysis with primary data from a survey and focus groups. The research objectives were first to establish design requirements through analysing these various input alternatives and secondly to combine this with user requirements. The consolidated design requirements were used to develop the content-based conceptual quay wall container modelling framework. The model development was followed with a verification and validation process.

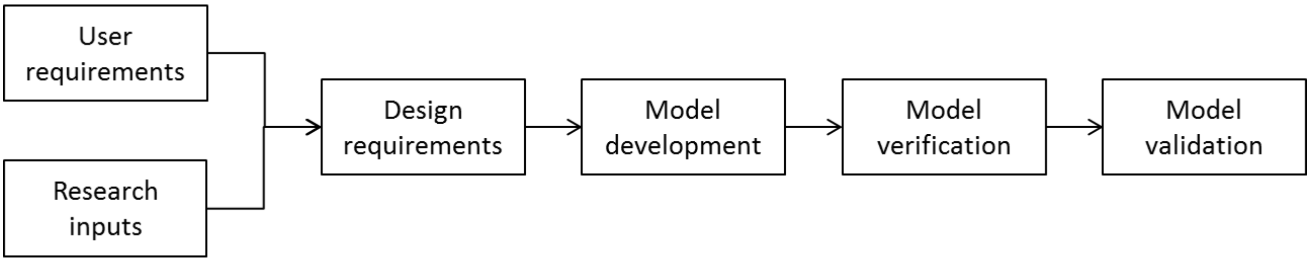


Figure 10.1: A simplified systems engineering approach for model development

The integrative nature of the various surface freight models used by Transnet to inform their long-term planning framework (LTPF), directed the user requirements to be closely aligned with the FDM.

To establish research inputs, the starting point was to analyse secondary data sources of historic container movements that was made available to the researcher. The secondary quantitative data analysis phase was followed by a primary research phase where inputs were obtained from supply chain decision-makers through a survey and focus groups to identify parameters and influencers that could impact container volumes in the future. In addition, this process served to confirm the quantitative findings and clarify any remaining questions. This mixed-methods research approach assisted the researcher to integrate and link the two aspects as follows:

- The priority was on collecting and analysing secondary quantitative data.

- The second phase of the research followed a supplementary qualitative component.

The research inputs were generated successfully using this mixed-methods research design in Chapters 2 through 6. The secondary quantitative datasets were collected from Transnet divisions, shipping lines, SARS, economists and industry bodies. These datasets were analysed and interpreted using mostly inductive generalisation to develop parameters and input values for the modelling frameworks. Following on this process, an industry survey and focus groups were designed. The primary data collection through these processes led to both quantitative and qualitative datasets. These were analysed and interpreted as either confirmation of earlier findings or further inputs to the modelling framework. Several research objectives were identified that relate to these research inputs. They are repeated from section 1.7.3 for convenience (with chapter references to indicate where they were addressed):

- Understand the state of the art in current container forecasting techniques and identify key learnings of relevance to this study (Chapter 3);
- Identify current and future trends in the global container trade (demand-side) and container trade infrastructure (supply-side) landscape that are of relevance to this study (Chapter 4);
- Identify data sources in the South African context that can be utilised both to inform and populate the forecasting models (Chapter 5);
- Understand the supply chain decisions that freight owners make and how these are expected to influence trends in South Africa's international trade container landscape (Chapter 6);

The research questions related to these objectives were listed in Table 1.3, and the answers to these research questions led to the design requirements identified in Chapters 2 through 6.

In Chapter 7 a consolidated design requirements list for the conceptual modelling framework for quay wall containers was established. The model was developed in Chapter 8 based on these design requirements providing insight into the various inputs, parameters and influencers identified. The model combined with the economic forecasting model of the demand and supply for commodities in the South African economy, is expected to provide a more accurate container forecast to port infrastructure planners based on the content of containers. Using these drivers in forecasting models will inform port planners towards calculated decisions on initiating and completing port container infrastructure projects at the right time.

The model building process was verified and the results validated in Chapter 9 by comparing actual TNPA container volumes with post-dated applications of the historically used GDP multiplier technique and the proposed content-based modelling technique.

10.3 Achievements

This dissertation's primary objective was to develop a content-based container flow forecast modelling framework to support the Transnet 30-year long-term planning framework (LTPF). This has been achieved in that the model outputs from the content-based model proposed in this dissertation were included in the 2014 base year forecast model for Transnet in their 2013–2043 Market Demand Strategy plans. Although the container model design was requested and sponsored by Transnet, the outputs and recommendations are independent.

The design requirements as defined in Chapter 7 are based on sound research principles utilising a wide range of research methods and provide an input that can be used not only for this model, but could also be beneficial for international container modellers to use. Minor adjustments might be required for their specific geographical and port legislative scenarios.

The first sub-objective was to understand the supply chain decisions that freight owners make and how this influences historic container trends. This could have been done by discussing the decisions with various freight owners, but the magnitude of such a task is too great. The alternative approach was followed by sourcing datasets from shipping lines. Analysing the datasets with representative sample sizes of the total import and export container volumes provided significant inputs into understanding the decisions from freight owners. The detail fields included in the datasets provided understanding of both the commodity and trade partner preferences. This detail was analysed and the derived modelling parameters were explained in Chapter 5.

The primary objective of this dissertation was to develop a content-based container forecasting model framework. This model has been defined and input values obtained from the analysis of historic shipping line data made available. Analysing the shipping line data to obtain all the various depths of knowledge related to this was an exhaustive, but rewarding task done with the support of a team of desktop researchers. The model has been used by Transnet port planners with positive feedback.

Confidence levels were introduced for inputs, parameters, influencers and outputs. This provides model users with an indication of where future improvements need to be done to ensure that the model accuracy is improved. Suggestions on where to improve and how to establish knowledge on 'Attention' points can be derived from the confidence levels indicated. Lower confidence levels need first attention.

The model verification versus the design requirements was done and validation of the outputs to ensure that the model does what it was intended to do. Selective output results were shown for each of the modelling segments.

10.4 Unique contributions

Supply chain practice is heavily dependent on demand forecasting, one of the critical steps required to equalise supply and demand of inventory, capacity or operations. It ensures lower carrying cost of unnecessary inventory and/or lower investments in unnecessary capacity. Forecasting techniques have long been important tools that infrastructure planning practitioners can use, but in the space of container port infrastructure theory they have proven to be limited in detail. A port is one element in an overarching transport and logistics network system. Forecasting models for container port infrastructure use limited input elements, often ignoring some of the high-level system influencers, or sometimes ignoring sub-elements of the system. The author believes this approach ignores important modelling elements. This is a concern given that at this stage over 65% of all tonnes globally traded over the quay wall are in containers.

The identification of a list of design requirements to move into content-based commodity forecasting is the first significant contribution from this dissertation. The engineering approach viewing the South African port system as an element to a bigger transport and logistics network system, while considering all the smaller elements contributing to this element provided a unique set of design requirements that would be beneficial wider than the South Africa scenario for better success in forecasting container requirements.

Global port planners can use this approach to use macro historic container content, to understand who their users are. They can then determine their specific requirements for the present and the medium-term future and propose modelling parameters that can be used to build a container forecast model. Such a model can then be built and validated against the current situation. Alternatively they could use some or all of the modelling elements proposed in this dissertation.

As explained, container demand forecasting is a case where economic theory (i.e. the macroeconomic structure of an economy's trade flows), supply chain practice (i.e. how the total logistics industry parcel and ship freight) and forecasting techniques overlap. This research filled some of the gaps in that theory by providing modelling techniques based on macroeconomic supply and demand patterns in the economy. The aim was to illustrate how global supply chains are often better understood from a national rather than a business perspective, but taking into account specific microbusiness requirements. Be it limited in extent, the process of including the micro views of business and supply chain practitioners into the design requirements identification, provided insight into confirming functional requirements and design restrictions and adding valuable attention points that will impact medium-term quay wall container volumes and types.

To date, many of the individual sections of this research have been done in isolation: some with success; others proving to be insignificant. This has been done in collaboration with Transnet Group Planning as the major user of the outputs. These projects provide valuable inputs to port, rail, pipeline and other macroscale infrastructure projects. Attempts have been made to integrate these influencing aspects on a port level, but with little success mainly due to constant time constraints in their capital investment planning cycle. The unique contribution of this research was to guide and direct the review of the last several years of data generated in this regard from various sources, to establish trends from this data, and develop a revised and improved set of input parameters for container modelling.

Another unique contribution was to validate the proposed input parameters with industry through focus groups and interviews and thus establish the macro-micro link between port infrastructure supply and parcelled freight requirements from industry.

10.5 Future work and recommendations

To improve accuracy and usefulness of the model a number of recommendations need to be made to Transnet and other entities that would wish to implement and use this modelling framework.

First, it is important to capture critical container data to improve the accuracy of input values. This would include both coastal and deep-sea container physical types and container volumes from the content as is available on container waybills. It is also important to distinguish between natural transhipments and domestic coastal container movements. This information forms the centre point of continued accurate input values for marine full container modelling typologies.

Another suggestion would be to perform annual model updates in order to build a history of input values and thus improve the accuracy of the outputs. Although this is an involved process requiring a high level of effort and various inputs, the question should be if port planners can afford to not do this. Annual comparison of modelled output values with actual volumes would reveal anomalies that can be researched to improve specific commodity input values that are in error. An annual update would ensure that the skills and experience required for these updates stay in place. If the update cycle is discontinued for a year or two it could be difficult or impossible to obtain the appropriate knowledge and skills to re-engage it.

Port planners should consider the volumes produced by the content based, validated demand framework proposed and use this as input in their container volume modelling exercises. The model does not make provision for phased in infrastructure expansion projects, additional capacity for safety reasons and risk management, quarterly seasonal fluctuations or other port specific scenario plans. Port planners should thus still consider these aspects to ensure that they provide sufficient capacity at the right moment in time.

The focus group and survey was not representative of all industries and if a wider focused knowledge pool could be accessed, some of the inputs with lower confidence levels can be improved significantly. Focused research efforts should be performed to chip away at inaccuracies. This focus should be on aspects with the highest volume contributions and the lowest confidence levels as indicated in Chapter 8.

The models for transhipments and empty containers are rather complex and the confidence levels in some of the input values are very low. Implementation of these models should be considered carefully, since the effort versus the accuracy might deem easier, more robust techniques to be sufficient. This is especially true for the modelling parameters for transhipments, coastwise and empty containers.

The influence and continuation of packing and unpacking of containers closer to port is a phenomenon that needs to be better understood from a rail market share perspective. This has relevance to the quay wall container volumes from a port-hinterland corridor cooperation perspective. Further research would benefit the understanding of the far hinterland opportunities into sub-Saharan Africa and also empty container modelling.

With a model built on container content the option is there for transport infrastructure planners, government and industry to plan long-term specific interventions in collaboration. This could ensure that the infrastructure supports these plans, and that interventions to address major South African challenges such as job creation, wealth generation and poverty alleviation happen in a coordinated and successful manner.

10.6 Concluding remarks

The first content-informed container forecasting model based on the derived design requirements has been developed and included in the Transnet 30-year long-term planning framework (LTPF). Feedback from the port planners and users was positive. A continuous updating cycle over several years will build further in-depth knowledge and improve confidence in the outputs throughout the user group.

It has been a pleasure to be involved in this groundbreaking work over the past 11 years. It was a satisfying journey being involved in the first prototypes of the FDM, seeing it develop over the years in both complexity and accuracy, and witnessing its growth in confidence and stature with both developers and users alike. I can only wish that the same focus, dedication, funding and appreciation will be endowed to the container forecasting model developed in this dissertation.

BIBLIOGRAPHY

APM Terminals. (2017). *Innovation*. Retrieved October 2, 2017, from APM Terminals: http://www.apmterminals.com/en/about-us/innovation

Back of Port Harbour Development . (2012). *Africa's Planned Growth Without the People*. Retrieved September 4, 2015, from https://backofport.wordpress.com/

Ballou, R. H. (2004). *Business Logistics/Supply Chain Management.* New Jersey: Pearson Prentice Hall.

Batchelor, R., & Bowe, C. (1974). 'Forecasting UK international trade: a general equilibrium approach'. *Applied Economics, 6, 2, p. 109., 6*(2), 109.

Bilegan, I., Craininc, T., & Gendreau, M. (2007). Forecasting freight demand at intermodal terminals using neural networks. Phuket, Thailand: Sixth Triennial Symposium on Transportation Analysis (TRISTAN).

Boehm, B. (1984). Verifying and Validating Software Requirements and Design Specifications. *IEEE Software Volume 1 Issue 1*, 75-88 .

Brown, T., & Hatch, A. (2002). *The value of rail intermodal to the US economy.* Retrieved September 5, 2017, from The American Association of State Highway and Transportation Officials: Special Committee on Intermodal Transportation and Economic Expansion: http://intermodal.transportation.org/Documents/brown.pdf

Budget Shipping Containers. (2017). *How many shipping containers are there in the world*. Retrieved June 19, 2017, from http://www.budgetshippingcontainers.co.uk/info/how-many-shipping-containers-are-there-in-the-world/

Business Day Live. (2014). *Transnet meets resistance in drilling for Durban dig out port*. Retrieved September 4, 2015, from http://www.bdlive.co.za/business/transport/2014/03/05/transnet-meets-resistance-in-drilling-for-durban-dig-out-port

Business Day Live. (2015). *Business Day Live*. Retrieved September 7, 2015, from http://container-mag.com/2015/03/03/durban-terminal-dig-port-given-2021-start-date/

Buswell, T. (2013). *State Govt adds support for rail to move freight*. Retrieved Feb 25, 2014, from http://www.mediastatements.wa.gov.au/pages/StatementDetails.aspx?listName=StatementsBarnett&StatId=7234

Castillo-Manzano, J., González-Laxe, F., & López-Valpuesta, L. (2013). Intermodal connections at Spanish ports and their role in capturing hinterland traffic. . *Ocean & Coastal Management, 86*(1).

Chen, S., & Chen, J. (2010). Forecasting container throughputs at ports using genetic programming. *Expert Systems with Applications, 37*(3), 2054-2058.

Citrus Growers Association. (2015). *Annual Report 2015.* Hillcrest, KZN: Citrus Growers Association of Southern Africa.

Clarkson Research. (2016, January 1). *World Cellular Containership Fleet 2016.* Retrieved July 13, 2017, from https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiI6N6OkdzUAhUHOhQKHeYAC2gQFggkMAA&url=http%3A%2F%2Faapa.files.cms-plus.com%2FStatistics%2FWORLD%2520CELLULAR%2520CONTAINERSHIP%2520FLEET%25202016.pdf&usg=AFQjCNFUPOEv-d0don5Ktf7Q

Container Auction. (2017). *Shipping container types and their common uses*. Retrieved June 19, 2017, from https://containerauction.com/read-news/shipping-container-types-and-their-common-uses1

Container Management. (2015). *Durban 'dig-out port' is given 2021 start date*. Retrieved November 1, 2016, from http://container-mag.com/2015/03/03/durban-terminal-dig-port-given-2021-start-date/

Container Management. (2015). *Durban terminal dig port given 2021 start date*. Retrieved September 04, 2015, from http://container-mag.com/2015/03/03/durban-terminal-dig-port-given-2021-start-date/

Containership Info. (2017). *MSC Sola*. Retrieved June 26, 2017, from http://www.containership-info.com/vessel_9401104.html

Coto-Millán, P., Fernández, X. L., Pesquera, M. A., & Agüeros, M. (2016). Impact of logistics on technical efficiency of world production (2007–2012). . *Networks and Spatial Economics, 16(4)*, 981–995. doi:10.1007/s11067-015-9306-6

Creswell, J. (2012). *Educational research: planning, conducting, and evaluating quantitative and qualitative research* (4 ed.). Boston, MA: Pearson Education.

Creswell, J. (2012). *Educational research: planning, conducting, and evaluating quantitative and qualitative research* (4 ed.). Boston, MA: Pearson Education.

Creswell, J., & Plano Clark, V. (2011). *Designing and conducting mixed methods research* (2 ed.). Thousand Oaks, CA: Sage.

Dagenais, M., & Martin, F. (1987). Forecasting Containerised Traffic for the Port of Montreal (1981-1995). *Transportation Research Part A: General, Policy and Practice, 21*(1), 1-16.

Davis, H. (1983). 'Regional Port Impact Studies: A Critique and Suggested Methodology'. *Transportation Journal (American Society Of Transportation & Logistics Inc), 23*(2), 61-71.

De Bod, A., & Havenga, J. (2010). Sub-Saharan Africa's rail freight transport system: potential impact of densification on cost. *Journal of Transport and Supply Chain Management, 4*(1).

De Jong, G., Gunn, H., & Walker, W. (2004). National and international freight transport models: Overview and ideas for future development. *Transport Reviews, Vol. 24 No. 1*, 103-124.

De Langen, P. (2003). Forecasting Container Throughput: A method and Implications for Port Planning. *Journal of International Logistics and Trade, 1*(1), 29-39.

Department of State and Regional Development of New South Wales. (2011). *The Southern Highlands Intermodal - Demand Forecasts*. Retrieved June 6, 2011, from http://www.southernhighlandsbusiness.com/forcast.html

Department of State and Regional Development of New South Wales. (2011). *The Southern Highlands Intermodal – Demand Forecasts.* Retrieved June 6, 2011, from http://www.southernhighlandsbusiness.com/forcast.html

Department of Trade and Industry. (2017). *Industrial Policy Action Plan 2017/18-2019/20*. Retrieved August 23, 2017, from http://www.dti.gov.za/industrial_development/industrial_development.jsp

Drewry. (2008). *Gardiner, N. 2007. Annual Container Market Review and Forecast – 2007/08: Incorporating the container forecaster – 3Q07.* London: Drewry.

Drewry. (2015). *Drewry Reports.* London: Drewry.

Drewry. (2016). *Another two years of misery, says Drewry*. Retrieved May 2016, from http://www.heavyliftpfi.com/news/another-two-years-of-misery-says-drewry.html

Drewry Maritime Advisors. (2013). *South Africa Ports Vessel Size Analysis.* London, United Kingdom: WSP Group Africa.

Economic Development Department. (2011). *The new growth path: Framework*. Retrieved August 22, 2017, from http://www.economic.gov.za/communications/publications/new-growth-path-series

European Commission Global Environment Monitoring Unit. (2012, Jul 20). *A Map of the World's Shipping Lanes*. Retrieved September 22, 2017, from The Atlantic: https://www.theatlantic.com/international/archive/2012/07/see-map-worlds-shipping-lanes/325643/

Fin24. (2017). *Strong growth in container exports for first quarter of 2017*. Retrieved August 22, 2017, from http://m.fin24.com/fin24/Companies/Industrial/strong-growth-in-container-exports-for-first-quarter-of-2017-20170613

Foster, V., & Briceño-Garmendia, C. (2009). *Africa’s Infrastructure: A Time for Transformation. .* Washington, DC: World Bank.

Fraser, D., & Notteboom, T. (2012). Gateway and hinterland dynamics: The case of the Southern African container seaport system. *African journal of business management, 6*(44), 10807-10825.

Free Dictionary. (2016). *Free Dictionary*. Retrieved October 25, 2016, from http://www.thefreedictionary.com/parameter

Fung, K. (2001). Competition between the ports of Hong Kong and Singapore: a structural vector error correction model to forecast the demand for container handling services. *Maritime Policy Management, 28*(1), 3-22.

Gain Group; Urban-Econ Development Economists. (2014, September 15). Final Project Report. *Demand forecasting of containerised cargo volumes through Southern African ports (2013-2043)*. Stellenbosch: Transnet Internal Project Documentation.

Garratt, M. (2006). *Forecasting for long-term investment in the container shipping industry – a holistic approach.* . Retrieved July 18, 2011, from http://www.mdst.co.uk/attachments/downloads/Hamburg_Dec06.pdf

Goldberg, J. (2013). *Israel invests in railfreight capacity*. Retrieved from http://www.railjournal.com/index.php/middle-east/israel-invests-in-rail-freight-capacity.html

Gosasang, V., Chandraprakaikul, W., & Kiattisin, S. (2010). An Application of Neural Networks for Forecasting Container Throughput at Bangkok Port. *World Congress on Engineering.* London: Imperial College London.

Grain South Africa. (2017). *Supply and demand scenarios for South Africa's maize market: Looking into the 2015/2016 and 2016/2017 marketing years*. Retrieved June 30, 2017, from http://www.grainsa.co.za/supply-and-demand-scenarios-for-south-africa-s-maize-market:-looking-into-the-2015/2016-and-2016/2017-marketing-years

Guttal, S. (2012). The urgent need for a paradigm shift. *Forum for Development Studies, 39(1)*, 125–130.

Havenga, J. H. (2007). *The development and application of a freight transport flow model for South Africa.* Stellenbosch: Stellenbosch University.

Havenga, J. H., Simpson, Z. P., & Goedhals-Gerber, L. (2017). International trade logistics costs in South Africa: Informing the port reform agenda. *Research in Transportation Business & Management*. doi:http://dx.doi.org/10.1016/j.rtbm.2016.08.006

Havenga, J. H., Simpson, Z. P., & Goedhals-Gerber, L. (2017). International trade logistics costs in South Africa: Informing the port reform agenda. *Research in Transportation Business & Management,*. doi:http://dx.doi.org/10.1016/j.rtbm.2016.08.006

Havenga, J. H., Simpson, Z. P., Fourie, P. F., & de Bod, A. (2011). Sustainable freight transport in South Africa: Domestic intermodal solutions. *Journal of Transport and Supply Chain Management; Vol 5, No 1*, 149-169. doi:10.4102/jtscm.v5i1.26

Havenga, J., & Van Eeden, J. (2011). Forecasting South African containers for international trade: A commodity-based approach. *Journal of Transport and Supply Chain Management, 5*(1).

Havenga, J., Simpson, Z., & De Bod, A. (2014). Deconstructing Container Forecasting: Commodity-Based Supply Chain Analysis. Windsor, Ontario, Canada: Canadian Transportation Research Forum’s 49th Annual Conference.

Hellenic Shipping News. (2018, Jan 29). *African container trades is growing exponentially despite bottlenecks and ports inefficiency*. Retrieved from Hellenic Shipping News: http://www.hellenicshippingnews.com/african-container-trades-is-growing-exponentially-despite-bottlenecks-and-ports-inefficiency/

Hesse, M. (2006). 'Global Chain, Local Pain: Regional Implications of Global Distribution Networks in the German North Range'. *Growth & Change, 37*(4), 570-596.

Ho, K., Ho, M., & Hui, C. (2008). 'Structural Dynamics in the Policy Planning of Large Infrastructure Investment under the Competitive Environment: Context of Port Throughput and Capacity'. *Journal of Urban Planning & Development, 134*(1), 9-20.

IMF. (2017, July). *World Economic Outlook Update*. Retrieved July 31, 2017, from https://www.imf.org/en/Publications/WEO/Issues/2017/07/07/world-economic-outlook-update-july-2017

IndexMundi. (2011). *GDP (purchasing power parity)*. Retrieved July 14, 2011, from http://www.indexmundi.com/g/g.aspx?c=xx&v=65

IndexMundi. (2016). *GDP (purchasing power parity)*. Retrieved June 2016, from http://www.indexmundi.com/g/g.aspx?v=65&c=xx&l=en

Indian Ports Association. (2016). *Indian Ports Association (IPA) TEU Volume Report*. Retrieved May 2016, from http://www.ipa.nic.in/index1.cshtml?lsid=22

Internationaional Union of Railways (UIC). (2012). *2012 Report on combined transport in Europe.* Retrieved September 5, 2017, from uic.org/IMG/pdf/2012_report_on_combined_transport_in_europe.pdf

International Monetary Fund. (2014). *World Economic Outlook Database*. Retrieved May 31, 2014, from http://www.imf.org/external/pubs/ft/weo/2013/01/weodata/index.aspx

International Trade Centre. (2017). *Trade Map*. Retrieved June 30, 2017, from http://www.trademap.org/

Ivanova, O. (2014). *Modelling Inter-Regional Freight Demand with Input-Output, Gravity and SCGE Methodologies.* (L. Tavasszy, & G. De Jong, Eds.) London: Elsevier.

JICA (Japan International Cooperation Agency). (2010). *Preparatory Survey on the Walvis Bay Port: Container Terminal Development Project in the Republic of Namibia.* Walvis Bay, Namibia: Walvis Bay: Statistics section of business division of Intelligence, Namport.

Journal of Commerce. (2016). *Container carriers ramp up scrapping*. Retrieved May 2016, from http://www.joc.com/maritime-news/container-carriers-ramp-scrapping-demand-and-rates-wane_20160418.html

Journal of Commerce. (2017, August 10). *Top 50 Container Ports in 2016: Shanghai tightens grip on crown*. Retrieved October 12, 2017, from Journal of Commerce: https://www.joc.com/port-news/top-50-container-ports-2016-shanghai-tightens-grip-crown_20170810.html

Kaluza, P., Kölzsch, A., Gastner, M. T., & Blasius, B. (2010). The complex network of global cargo ship movements. *Journal of the Royal Society Interface, 7*, 1093-1103. doi:10.1098/rsif.2009.0495

Kawakami, T., & Doi, M. (2004). 'Port capital formation and economic development in Japan: A vector autoregression approach'. *Papers In Regional Science, 83, 4, pp. , 83*(4), 723-732.

Koppen, I. J. (1995). Dispelling the myths of transport growth: a critical appraisal and some introductory remarks. *World Transport Policy & Practice, 1*(2), 4-6.

Lam, W., Pan, L., Seabrooke, W., & Hui, E. (2004). Forecasts and Reliability Analysis of Port Cargo Throughput in Hong Kong. *Journal of Urban Planning and Development*.

Lee, L. H., Chew, E. P., & Lee, L. S. (2006). Multicommodity network flow model for Asia's container ports. *Maritime Policy & Management, 33*(4), 387-402.

Leontief, W. (1986). *Input-output economics.* Oxford: Oxford University Press.

Los Angeles Times. (2015). *Imports plunged at West Coast ports amid labor dispute*. Retrieved July 6, 2017, from http://www.latimes.com/business/la-fi-west-coast-port-decline-20150317-story.html

Malloy, T. (2012). *IANA Intermodal Market Trends & Statistics.* Retrieved July 13, 2017, from http://www.fiata.com/uploads/media/FIATA_World_Congress_2012_MTI_-_Presentation_by_Mr_Tom_Malloy__Thouroughbred_Direct_Intermodal_Services_02.pdf

Marine Insight. (2017). *16 types of container unit and designs for shipping cargo*. Retrieved June 19, 2017, from http://www.marineinsight.com/know-more/16-types-of-container-units-and-designs-for-shipping-cargo/

Marinelink. (2016, November 14). *Record Containership Demolitions has suppressed Fleet Growth - Drewry*. Retrieved August 30, 2017, from Marinelink: https://www.marinelink.com/news/containership-demolitions418224

Mather, A. (2013). *Overview of the Proposed Durban Dig-Out Port Project (DDOP).* Durban: Transnet. Retrieved September 25, 2015, from http://c.ymcdn.com/sites/www.projectmanagement.org.za/resource/resmgr/andrew_mather.pdf

Mchizwa, N. (2014). Towards efficient port pricing: a specific look into South African tariff methodology. *Towards efficient port pricing: a specific look into South African tariff methodology*. World Maritime University.

McKinsey & Company. (2016, June). *Bridging global infrastructure gaps*. Retrieved August 18, 2017, from http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/bridging-global-infrastructure-gaps

Monios, J., Notteboom, T., Wilmsmeier, G., & Rodrigue, J. (2016). *Competition and complementarity between seaports and hinterlands for locating distribution activities.* Chios, Greece: PortEconomics.

Mostafa, M. (2004). Forecasting the Suez Canal traffic: a neural network analysis. *Maritime Policy & Management, 31*(2), 139-156.

Mouton, J. (2013). *How to succeed in your Master's & Doctoral Studies: A South African Guide and Resource Book. 18th Impression. .* Pretoria: Van Schaik.

Mpumalanga Department of Public Works, Roads and Transport. (2009). *Maputo Port Activity: Mpumalanga Province Freight Data Bank.* Nelspruit: Department of Public Works, Roads and Transport.

Müller, S., Wolfermann, A., & Huber, S. (2012). A nation-wide macroscopic freight traffic model. *Procedia - Social and Behavioural Sciences, Vol, 54*, (pp. 221-230).

Nash-Hoff, M. (2016). *Is reshoring increasing or declining?* Retrieved June 28, 2016, from Industry Week: http://www.industryweek.com/global-economy/reshoring-increasing-or-declining

News24. (2012). *Largest container ship in SA docks in Durban*. Retrieved July 5, 2017, from http://www.news24.com/SouthAfrica/News/Largest-container-ship-in-SA-docks-in-Durban-20120705

Neylan, P. (2010). *4Q10, Quarterly forecasts of the container market.* London: Drewry.

Njoh, A. (2009). 'The Development Theory of Transportation Infrastructure Examined in the Context of Central and West Africa'. *Review Of Black Political Economy, 36, 3/4, pp. , 36*(3/4), 227-243.

Notteboom, T. (2005). Port regionalization: towards a new phase in port development. *Maritime Policy and Management, 32*(3), 297–313.

Notteboom, T. (2005). Port regionalization: towards a new phase in port development. *Maritime Policy and Management, 32*(3), 297–313.

Notteboom, T. (2010). From multi-porting to a hub port configuration: the South African container port system in transition. *International Journal of Shipping and Transport Logistics, 2(2), 2*(2), 224-245.

Notteboom, T. (2011). An application of multi-criteria analysis to the location of a container hub port in South Africa. *Maritime Policy & Management, 38*(1), 51 — 79.

Notteboom, T. (2012). Towards a new intermediate hub region in container shipping? Relay and interlining via the Cape route vs. the Suez route. *Journal of Transport Geography, 22*, 164-178.

Notteboom, T., & Rodrigue, J. (2009). The future of containerization: perspectives from maritime and inland freight distribution. *Geo Journal, 74*(1), 7-22.

Nurosidah, S. (2017). The shift of containerisation influence: 50-year logistics innovation in international business. *The Business & Management Review, Vol. 8 No. 4*, 93-98.

Ocean Shipping Consultants. (2011). *North European container port markets to 2020.* Ocean Shipping Consultants Limited.

Ogard, L. (2013). Enhancing and Expanding Containerized Commodity Movements. Joliet Illionois: University of St. Francis in Joliet Illionois. Retrieved July 13, 2017, from http://www.ilsoy.org/_data/files/isa/Transportation/2013%20Summit%20Presentations/09_Logard.pdf

OOCL. (2017). *OOCL Hong Kong*. Retrieved June 26, 2017, from http://www.oocl.com/eng/ourservices/serviceroutes/aet2/Pages/default.aspx

OOCL. (2017). *OOCL reaches milestone with the christening of the OOCL Hong Kong*. Retrieved June 27, 2017, from http://www.oocl.com/eng/pressandmedia/pressreleases/2017/Pages/12may17.aspx

Pallis, A., Vitsounis, T., De Langen, P., & Notteboom, T. (2011). Port economics, policy and management: Content classification and survey. *Transport Reviews, 31*(4), 445-471.

Phakathi, B. (2017). *Slow GDP growth 'will curtail NDP targets'*. Retrieved August 22, 2017, from Business Day. 14 February: https://www.businesslive.co.za/bd/economy/2017-02-14-slow-gdp-growth-will-curtail-ndp-targets/

Pienaar, W. J., & Vogt, J. J. (2016). *Business Logistics Management (fifth edition).* Cape Town: Oxford University Press Southern Africa.

Pienaar, W., Havenga, J., Simpson, Z., & van Eeden, J. (2012). LONG TERM CONTAINER VOLUME FORECASTING: DECOUPLING GROSS DOMESTIC PRODUCT AND CONTAINER MOVEMENTS. *CORPORATE OWNERSHIP \& CONTROL, 9*(3), 217-229.

Plummer, P. (2013). *Long Term Planning Process: Freight Market Study Draft for Consultation.* (London: Network Rail) Retrieved July 13, 2017, from https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiWp_bu6obVAhXLB8AKHSIcCX0QFggiMAA&url=https%3A%2F%2F16cbgt3sbwr8204sf92da3xxc5m-wpengine.netdna-ssl.com%2Fwp-content%2Fuploads%2F2016%2F11%2FFreight-Market-Study.pdf&usg=AFQjCNFv

Port Finance International. (2017). *Walvis Bay expansion on track for 2017*. Retrieved July 2013, 2017, from http://www.portfinanceinternational.com/categories/emerging-economies/item/2030-walvis-bay-expansion-on-track-for-2017

Port of Maputo. (2017). *Container Terminal*. Retrieved July 2013, 2017, from http://www.portmaputo.com/terminal/container-terminal/

Port Strategy. (2017). *Containership fleet outpaces port development*. Retrieved June 26, 2016, from http://www.portstrategy.com/news/port-profile/containership-fleet-outpaces-port-development

Portnews. (2015). *Drewry predicts average global container port demand growth of 4.5% per annum through to 2019*. Retrieved April 2016, from http://en.portnews.ru/news/205280/

Portnews. (2015). *Drewry predicts average global container port demand growth of 4.5% per annum through to 2019*. Retrieved August 28, 2015, from http://en.portnews.ru/news/205280

Ports Regulator of South Africa. (2012, April 1). *Container Port Tariff Comparator Study 01/04/2012 .* Retrieved September 27, 2013, from http://www.portsregulator.org/images/documents/Part_D_Container_Port_Tariff_Comparator_Study_01042012.pdf

Raghuram, G., & Gangwar, R. (2007). *Containerization: building global trade competitiveness.* Ahmedabad, India: Indian Institute of Management India.

Raza, M., & Aggarwal, Y. (1986). *Transport Geography of India: Commodity flows and the regional structure of the Indian economy.* New Delhi: Concept Publishing Company. Retrieved September 7, 2016, from https://books.google.com/books?isbn=8170220890

Rodrigue, J. (2016). The Role of Transport and Communication Infrastructure in Realising Development Outcomes . In J. Grugel, & D. Hammett, *The Palgrave Handbook of International Development.* London: Palgrave Macmillan.

Rodrigue, J., & Notteboom, T. (2015). Looking inside the box: evidence from the containerization of commodities and the cold chain. *Maritime Policy & Management, 42*(3), 207-227. doi:10.1080/03088839.2014.932925

Rodrigue, J., & Slack, B. (2017). *Intermodal Transportation and Containerization*. Retrieved July 13, 2017, from https://people.hofstra.edu/geotrans/eng/ch3en/conc3en/ch3c6en.html

Royal Haskoning DHV; IMANI Development. (2013). *Status Quo Report: Development of an integrated freight and logistics strategic framework and action plan.* Durban, South Africa: Strategic Transport Planning Department - ETA.

Ryckewaert, M. (2010). The Ten-Year Plan for the port of Antwerp (1956-1965): a linear city along the river. *Planning Perspectives, 25*(3), 303-322.

SADC. (2012). *SADC Regional Infrastructure Development Master Plan. Transport Sector Plan (Aug 2012).* SADC.

Salin, D. (2010). *Impact of Panama Canal Expansion on the US Intermodal System (No. 147032). .* USA: United States Department of Agriculture, Agricultural Marketing Service, Transportation and Marketing Program.

Salisbury. (2015). *Journal of Commerce Top 50 World Container Ports 2014*. Retrieved April 2016, from http://www.joc.com/port-news/international-ports/joc-top-50-world-container-ports_20150820.html

SAMSA. (2012). *Ports Services – Industry Profile.* Retrieved July 1, 2016, from http://www.samsa.org.za/sites/samsa.org.za/files/port_services_industry_profile_2_0_0.pdf

SARS. (2017). *SARS: SIC codes*. Retrieved April 24, 2017, from http://www.sars.gov.za/TaxTypes/PAYE/ETI/Pages/SIC-Codes.aspx

Sharp, L. (2015). *Eskom hurting SA's ailing economy - outages slowing growth*. Retrieved September 25, 2015, from http://www.sowetanlive.co.za/business/2015/02/21/eskom-hurting-sa-s-ailing-economy---outages-slowing-growth

Singh, A. (2005). Future Trends in Global Ports--Managing Growth in an Era of Mergers and Acquisitions. *Thailand: LCB Container Terminal, 1*.

Sooredoo, N. (2013). *Historical TEU throughput (information kindly provided on request directly by Drewry).* London: Drewry.

South African Reserve Bank. (2016). *GDP - Reserve bank series*. Retrieved August 30, 2017, from Online download facility: https://www.resbank.co.za/Research/Statistics/Pages/OnlineDownloadFacility.aspx

Statista. (2017). *Number of TEUs of the global containership fleet*. Retrieved June 26, 2017, from https://www.statista.com/statistics/198391/number-of-teus-of-the-global-containership-fleet/

Statistics South Africa. (2015). *Gross Domestic Product Second Quarter 2015.* Retrieved May 18, 2016, from http://www.statssa.gov.za/publications/P0441/P04412ndQuarter2015.pdf

Statistics South Africa. (2017). *Stats SA*. Retrieved April 24, 2017, from http://www.statssa.gov.za/

Sustainable Aotearoa New Zealand. (2009). *Strong Sustainability for New Zealand: Principles and Scenarios.* Auckland: Nakedize Limited.

Syafi'i, Kuroda, K., & Takebayashi, M. (2005). Forecasting the demand of container throughput in Indonesia. *Memoirs of Construction Engineering Research Institute, 47*.

Tavasszy, L. (2006). Freight modelling - An overview of international experiences. *TRB Conference on freight demand modelling: Tools for public sector decisionmaking.* Washington DC.

Tavasszy, L., & De Jong, G. (2014). *Modelling freight transport.* Amsterdam: Elsevier.

The Economist. (2014). *The trillion-dollar gap*. Retrieved July 6, 2017, from https://www.economist.com/news/leaders/21599358-how-get-more-worlds-savings-pay-new-roads-airports-and-electricity

The Loadstar. (2017). *Container shipping M&A activity expected smaller carriers try keep*. Retrieved June 21, 2017, from https://theloadstar.co.uk/container-shipping-ma-activity-expected-smaller-carriers-try-keep/

TNPA. (2017). TNPA data sources. Johannesburg, South Africa: TNPA.

Trade Risk Guaranty. (2017). *14 Common shipping container types*. Retrieved June 19, 2017, from https://traderiskguaranty.com/trgpeak/14-common-shipping-container-types/

Transnet. (2016). *Transnet Overview*. Retrieved August 21, 2016, from https://www.slideshare.net/williecoetsee/transnet-and-tpt-overview-12-sept-2016

Transnet. (2017). *Annual results – Integrated Report 2017.* Retrieved August 20, 2017, from https://www.transnet.net/InvestorRelations/AR2017/Transnet%20IR%202017.pdf

Transnet Port Terminals. (2017). *Durban Container Terminal*. Retrieved July 13, 2017, from http://www.transnetportterminals.net/Ports/Pages/Durban_Container.aspx

Transport World Africa. (2016). *Gama outlines Transnet plans*. Retrieved May 2016, from http://www.transportworldafrica.co.za/2016/04/19/gama-outlines-transnet-plans/

Turnquist, M. (2006). Characteristics of effective freight models. *Transportation Research Board Conference Proceedings (No. 40).* Washington D.C., United States. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.469.7890&rep=rep1&type=pdf#page=23

UN. (2014, 01 24). *UNSPSC.* Retrieved 06 14, 2017, from http://www.unspsc.org/Portals/3/Documents/20140124%20February%20UNSPSC%20Newsletter.pdf

UN Statistics Division. (2017). *SICS Rev.4: Detailed structure and explanatory notes*. Retrieved April 19, 2017, from https://web.archive.org/web/20081221030849/http://unstats.un.org:80/unsd/cr/registry/regcst.asp?Cl=27

UN Statistics Division. (2017). *SITC Rev.4: Detailed structure and explanatory notes*. Retrieved April 20, 2017, from http://web.archive.org/web/20120725235918/http://unstats.un.org:80/unsd/cr/registry/regcst.asp?Cl=28

UN Statistics Division. (2017). *Standard Industrial Trade Classification (SITC)*. Retrieved April 19, 2017, from https://web.archive.org/web/20081221030849/http://unstats.un.org:80/unsd/cr/registry/regcst.asp?Cl=27

UNCTAD. (2012). *UNCTAD Review of Maritime Transport 2012.* Retrieved July 13, 2017, from http://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx

UNCTAD. (2015). *UNCTAD Review of Maritime Transport 2015*. Retrieved July 13, 2017, from http://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx

UNCTAD. (2016). *Liner Shipping Connectivity Index*. Retrieved July 13, 2017, from http://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx?IF_ActivePath=P%2C11

UNCTAD. (2016). *UNCTAD Review of Maritime Transport 2016.* Retrieved July 13, 2017, from http://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx

UNESCAP. (2007). *Regional Shipping and Port Development – Container Traffic Forecast 2007 Update.* (U. E. Pacific, Ed.) New York: United Nations.

United Nations. (2017). *Sustainable Development Knowledge Platform: Sustainable Development Goal 9*. Retrieved August 17, 2017, from https://sustainabledevelopment.un.org/sdg9

Unknown. (2017). *Harmonized_System*. Retrieved April 20, 2017, from https://en.wikipedia.org/wiki/Harmonized_System

UNSD. (2017). *Classification by Broad Economic Categories, Defined in terms of SITC, Rev.3, (BEC Rev.3)*. Retrieved April 20, 2017, from https://web.archive.org/web/20080923170404/http://unstats.un.org:80/unsd/class/family/family2.asp?Cl=10

US Department of Defense. (2001). *Systems engineering fundamentals.* Retrieved August 20, 2017, from Supplementary text prepared by the Defense Acquisition University Press, Fort Belvoir, Virginia: https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-885j-aircraft-systems-engineering-fall-2005/readings/sefguide_01_01.pdf

US Department of Transportation. (2008). *Glossary of Shipping Terms.* Washington: Maritime Administration.

Van Aken, J., Berends, H., & van der Bij, H. (2006). *Problem Solving in Organizations: A Methodological Handbook for Business Students.* Cambridge: Cambridge University Press.

Veenstra, A., & Notteboom, T. (2011). The development of the Yangtze River container port system. *Journal of Transport Geography, 19*(4), 772-781.

WCO. (2017, Feb). *WCO Online Bookshop: WCO News #82.* Retrieved April 20, 2017, from http://wcoomdpublications.org/?___store=english&___from_store=french

WCO. (2017). *World Customs Organisation: What is the Harmonized System (HS)?* . Retrieved April 20, 2017, from http://www.wcoomd.org/en/topics/nomenclature/overview/what-is-the-harmonized-system.aspx

Wikipedia. (2017). *Industry classification*. Retrieved April 19, 2017, from https://en.wikipedia.org/wiki/Industry_classification

Wilson, W., & De Vuyst, E. (2007). *Optimization Models of Container Shipments in North America: Spatial Competition and Projections (Methodology).* Fargo, ND: North Dakota State University.

World Bank. (2016a). *Global Infrastructure Facility*. Retrieved July 10, 2016, from http://www.worldbank.org/en/programs/global-Infrastructure-facility

World Shipping. (2017). *About the industry: Containers*. Retrieved June 19, 2017, from http://www.worldshipping.org/about-the-industry/containers

World Shipping. (2017). *Cargo Weight*. Retrieved June 19, 2017, from http://www.worldshipping.org/industry-issues/safety/cargo-weight

World Shipping. (2017). *Global container fleet*. Retrieved June 19, 2017, from http://www.worldshipping.org/about-the-industry/containers/global-container-fleet

WorldBank. (2013). *World Development Indicators*. Retrieved August 31, 2013, from http://data.worldbank.org/data-catalog/world-development-indicators

WorldBank. (2016b). *Connecting to Compete 2016 – Trade logistics in the global economy.* Retrieved March 1, 2017, from The Logistics Performance Index and its indicators: https://openknowledge.worldbank.org/bitstream/handle/10986/24598/Connecting0to00n0the0global0economy.pdf

WorldBank. (2016b). *Connecting to Compete 2016 – Trade logistics in the global economy. The Logistics Performance Index and its indicators.* Retrieved March 1, 2017, from https://openknowledge.worldbank.org/bitstream/handle/10986/24598/Connecting0to00n0the0global0economy.pdf

Worldfolio. (2016). *Meeting the world's infrastructure requires huge investments*. Retrieved 2016, from http://www.theworldfolio.com/news/meeting-the-worlds-infrastructure-requires-huge-investments/4086/

Yap, W., & Lam, J. (2006). Competition dynamics between container ports in East Asia. . *Transportation Research Part A: Policy and Practice,, 40*(1), 35-51.

Yap, W., Lam, J., & Notteboom, T. (2006). Developments in container port competition in East Asia. *Transport Reviews, 26*(2), 167-188.

Zaman, K., & Shamsuddin, S. (2017). Green logistics and national scale economic indicators: Evidence from a panel of selected European countries. *Journal of Cleaner Production, 143*, 51-63. doi:10.1016/j.jclepro.2016.12.150

APPENDIX A – COMMODITY GROUPINGS USED IN TRANSNET MODELLING

The project team supporting Transnet in their group planning efforts has over the course of more than ten years developed a list of commodity groups that provide sufficient detail for their various planning levels and divisions within the business. The level of detail included in these commodity groupings have been refined over and again over during these years and have stabilised on the commodity groups that will be used during this dissertation.

The table on the next page provides the complete list of commodity groups. A short explanation of each field is necessary:

- **Code**: Unique code used in various different divisions for planning and reporting to link databases to the modelling outputs.
- **Commodity Name**: Short descriptive detail about the commodity content.
- **Commodity index**: Index used by planning team for cross-referencing.
- **Modelling 4 letter code**: The SAS and Flowmap software used by the project team in the transport modelling, requires a 4 letter code for modelling and data management purposes.
- **Agr/Min/Mnft**: High level economic division that the commodity contributes towards.
- **Industry Group**: This grouping provides summary information for industry reports, and focus areas within the Transnet divisions.
- **Cargo type**: This grouping provides a view of the type of equipment and infrastructure needed to transport and move commodities between transport modes.

CODE	Commodity name	Commodity Index	MODELLING 4 LETTER CODE	Agr/Min/Mnft	Industry group	Cargo type
FDM10010	Barley	1	BARL	Agriculture	Grain	Agricultural dry bulk
FDM10020	Grain Sorghum	2	GRNS	Agriculture	Grain	Agricultural dry bulk
FDM10030	Maize	3	MAZE	Agriculture	Grain	Agricultural dry bulk
FDM10040	Sunflower Seed	4	SUNS	Agriculture	Other agriculture	Agricultural dry bulk
FDM10050	Wheat	5	WHEA	Agriculture	Grain	Agricultural dry bulk
FDM10060	Soya beans	6	SBEA	Agriculture	Other agriculture	Agricultural dry bulk
FDM10070	Rice	7	RICE	Agriculture	Grain	Agricultural dry bulk
FDM10080	Vegetables	8	VEGT	Agriculture	Other agriculture	Refrigerated
FDM10090	Potatoes	9	POTA	Agriculture	Other agriculture	Agricultural dry bulk
FDM10100	Cassava	10	CASS	Agriculture	Other agriculture	Agricultural dry bulk
FDM10110	Sugar cane	11	SUGA	Agriculture	Other agriculture	Agricultural dry bulk
FDM10120	Cotton	12	COTT	Agriculture	Other agriculture	Light break-bulk
FDM10130	Grapes	13	GRAP	Agriculture	Fruit	Refrigerated
FDM10140	Subtropical Fruit	14	SUBF	Agriculture	Fruit	Refrigerated
FDM10150	Citrus	15	CITR	Agriculture	Fruit	Refrigerated
FDM10160	Deciduous Fruit	16	DECF	Agriculture	Fruit	Refrigerated
FDM10170	Milk (bulk)	17	MILK	Agriculture	Other agriculture	Liquid bulk
FDM10180	Eggs (poultry)	18	EGGS	Agriculture	Other agriculture	Palletized
FDM10190	Fish and seafood	19	FISH	Agriculture	Other agriculture	Palletized
FDM10200	Other Agriculture	20	OAGR	Agriculture	Other agriculture	Agricultural dry bulk
FDM20010	Coal Mining Exports	21	COLE	Mining	Energy	Mining dry bulk
FDM20020	Coal Mining Domestic	22	COAL	Mining	Energy	Mining dry bulk
FDM20030	Coal Mining Power station	23	CPOW	Mining	Energy	Mining dry bulk
FDM20040	Coal Mining Sasol	24	CSAS	Mining	Energy	Mining dry bulk
FDM20050	Coal Mining Fly Ash	25	CFLY	Mining	Energy	Mining dry bulk
FDM20060	Crude oil	26	CRUD	Mining	Energy	Liquid bulk
FDM20061	Crude oil in Pipes	27	CRUP	Mining	Transport	Liquid bulk in Pipe Line
FDM20070	Iron Ore Exports	28	IRNE	Mining	Metal industries	Mining dry bulk
FDM20080	Iron Ore Domestic	29	IRON	Mining	Metal industries	Mining dry bulk
FDM20090	Precious metal ore	30	PORE	Mining	Other mining	Open skip bulk

CODE	Commodity name	Commodity Index	MODELLING 4 LETTER CODE	Agr/Min/Mnft	Industry group	Cargo type
FDM20100	Precious metals and precious stones (Refined)	31	PREC	Mining	Other manufactured products	Heavy break-bulk
FDM20110	Magnetite	32	MAGN	Mining	Metal industries	Mining dry bulk
FDM20120	Chrome	33	CHRO	Mining	Metal industries	Mining dry bulk
FDM20130	Copper	34	CPPR	Mining	Metal industries	Mining dry bulk
FDM20140	Manganese Exports	35	MNGE	Mining	Metal industries	Mining dry bulk
FDM20150	Manganese Domestic	36	MANG	Mining	Metal industries	Mining dry bulk
FDM20160	Titanium slag	37	TTNM	Mining	Metal industries	Mining dry bulk
FDM20170	Rutile	38	RUTI	Mining	Metal industries	Mining dry bulk
FDM20180	Ilmenite (Titanium ore)	39	ILME	Mining	Metal industries	Mining dry bulk
FDM20190	Alumina	40	ALUM	Mining	Metal industries	Open skip bulk
FDM20200	Gypsum	41	GYPS	Mining	Construction	Open skip bulk
FDM20210	Zircon	42	ZIRC	Mining	Construction	Open skip bulk
FDM20220	Stone	43	STON	Mining	Construction	Open skip bulk
FDM20230	Granite	44	GRAN	Mining	Construction	Open skip bulk
FDM20240	Limestone	45	LIME	Mining	Construction	Open skip bulk
FDM20250	Rock Phosphate	46	ROCK	Mining	Other mining	Open skip bulk
FDM20260	Sulphur	47	SULP	Mining	Other mining	Open skip bulk
FDM20270	Fluorspar	48	FLUO	Mining	Other mining	Open skip bulk
FDM20280	Salt	49	SALT	Mining	Other mining	Open skip bulk
FDM20290	Other Non-Ferrous Metal Mining	50	NFMM	Mining	Other mining	Mining dry bulk
FDM20300	Other Mining	51	OMIN	Mining	Other mining	Open skip bulk
FDM30010	Processed Foods	52	FOOD	Manufacturing	FMCG	Palletized
FDM30020	Slaughtered animal meat	53	MEAT	Manufacturing	Other agriculture	Refrigerated
FDM30030	Soya bean products	54	SOYP	Manufacturing	Other agriculture	Light break-bulk
FDM30040	Animal feed	55	FEED	Manufacturing	Other agriculture	Light break-bulk
FDM30050	Beverages	56	BEVE	Manufacturing	FMCG	Palletized
FDM30060	Tobacco Products	57	TABP	Manufacturing	FMCG	Palletized
FDM30070	Textile Products	58	TEXT	Manufacturing	FMCG	Light break-bulk
FDM30080	Wood timber and products	59	WOOD	Manufacturing	Other manufactured products	Heavy break-bulk
FDM30090	Wood chips	60	WCHP	Manufacturing	Other manufactured products	Heavy break-bulk

CODE	Commodity name	Commodity Index	MODELLING 4 LETTER CODE	Agr/Min/Mnft	Industry group	Cargo type
FDM30100	Paper	61	PAPR	Manufacturing	Other manufactured products	Heavy break-bulk
FDM30110	Pulp of wood and paper	62	PULP	Manufacturing	Other manufactured products	Heavy break-bulk
FDM30120	Recycled paper	63	RECY	Manufacturing	Other manufactured products	Heavy break-bulk
FDM30130	Printing and Publishing	64	PRNP	Manufacturing	Other manufactured products	Heavy break-bulk
FDM30140	Petrol	65	FUEL	Manufacturing	Energy	Liquid bulk
FDM30141	Petrol in Pipes	66	FUEP	Manufacturing	Transport	Liquid bulk in Pipe Line
FDM30150	Diesel	67	DIES	Manufacturing	Energy	Liquid bulk
FDM30151	Diesel in Pipes	68	DIEP	Manufacturing	Transport	Liquid bulk in Pipe Line
FDM30160	Jet fuel	69	JETF	Manufacturing	Energy	Liquid bulk
FDM39161	Jet fuel in Pipes	70	JETP	Manufacturing	Transport	Liquid bulk in Pipe Line
FDM30170	Other Petroleum Products	71	PETP	Manufacturing	Energy	Liquid bulk
FDM30180	Gas	72	GASS	Manufacturing	Energy	Liquid bulk
FDM30181	Gas in Pipes	73	GASP	Manufacturing	Transport	Liquid bulk in Pipe Line
FDM30190	Chemicals	74	CHEM	Manufacturing	Chemicals	Heavy break-bulk
FDM30200	Fertilizer	75	FERT	Manufacturing	Chemicals	Heavy break-bulk
FDM30210	Pharmaceutical Products	76	PHAR	Manufacturing	FMCG	Palletized
FDM30220	Bricks	77	BRIK	Manufacturing	Construction	Heavy break-bulk
FDM30230	Cement	78	CEME	Manufacturing	Construction	Heavy break-bulk
FDM30240	Iron & Steel	79	STEL	Manufacturing	Metal industries	Heavy break-bulk
FDM30250	Ferrochrome	80	FRCH	Manufacturing	Metal industries	Heavy break-bulk
FDM30260	Ferromanganese	81	FRMN	Manufacturing	Metal industries	Heavy break-bulk
FDM30270	Scrap metals	82	SCRP	Manufacturing	Metal industries	Heavy break-bulk
FDM30280	Metal products, machinery and electronic equipment	83	METL	Manufacturing	Other manufactured products	Heavy break-bulk
FDM30290	Motor vehicles and trucks	84	AUTO	Manufacturing	Automotive	Ro-ro tons
FDM30300	Motor Vehicle Parts & Accessories	85	MVPA	Manufacturing	Automotive	Palletized
FDM30310	Transport Equipment	86	TREQ	Manufacturing	Other manufactured products	Heavy break-bulk
FDM30320	Other Manufacturing Industries	87	OMNF	Manufacturing	Other manufactured products	Heavy break-bulk
FDM30330	Non-Ferrous Metal Products	88	NFMP	Manufacturing	Other manufactured products	Heavy break-bulk

APPENDIX B – PERCENTAGE CONTAINERISED INPUT TABLES

The shipping line data combined with the bulk TNPA volumes provides a set of data with percentages containerised for each of the commodities used within the Freight Demand Model (FDM), per port, per year for imports and exports.

The data fields included in this Appendix on the next page are:

- FDM # — Number used by the FDM
- FDM Name — Commodity Name
- Direction — Import or Export
- Port — This data was filtered for the Ports of Cape Town, Durban and Port Elizabeth
- Years — 2010, 2011, 2012, 2013, 2014
- Bulk Tonnes — Volume in bulk
- TEU tonnes — Volume in Containers
- 2014 Total — Total volume in tonnes

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM10010	**Barley**	Export	Cape Town	100.0%	100.0%	100.0%	0.0%	100.0%	-	22	22
FDM10010	**Barley**	Import	Cape Town	2.7%	0.4%	3.1%	2.6%	1.2%	43 395	543	43 938
FDM10010	**Barley**	Import	Durban	21.4%	44.2%	100.0%	17.4%	100.0%	-	1 580	1 580
FDM10010	**Barley**	Import	Port Elizabeth	100.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM10020	**Grain Sorghum**	Export	Cape Town	0.0%	0.0%	0.0%	100.0%	100.0%	-	11	11
FDM10020	**Grain Sorghum**	Export	Durban	100.0%	4.3%	42.5%	40.5%	100.0%	-	188	188
FDM10020	**Grain Sorghum**	Import	Cape Town	100.0%	100.0%	2.2%	100.0%	100.0%	-	491	491
FDM10020	**Grain Sorghum**	Import	Durban	85.9%	3.6%	0.3%	0.2%	0.4%	25 021	99	25 120
FDM10020	**Grain Sorghum**	Import	Port Elizabeth	100.0%	0.0%	0.0%	100.0%	100.0%	-	11	11
FDM10030	**Maize**	Export	Cape Town	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM10030	**Maize**	Export	Durban	0.5%	1.0%	0.0%	0.3%	1.0%	1 247 808	12 132	1 259 941
FDM10030	**Maize**	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM10030	**Maize**	Import	Cape Town	0.2%	0.0%	0.0%	0.0%	0.3%	79 673	223	79 896
FDM10030	**Maize**	Import	Durban	9.9%	100.0%	1.6%	100.0%	100.0%	-	1 314	1 314
FDM10030	**Maize**	Import	Port Elizabeth	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM10040	**Sunflower Seed**	Export	Durban	0.0%	0.0%	100.0%	100.0%	100.0%	-	46	46
FDM10040	**Sunflower Seed**	Import	Cape Town	1.2%	100.0%	-3.4%	10.4%	100.0%	-	299	299
FDM10040	**Sunflower Seed**	Import	Durban	100.0%	1.1%	5.4%	1.6%	0.3%	120 058	395	120 453
FDM10040	**Sunflower Seed**	Import	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM10050	**Wheat**	Export	Cape Town	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM10050	**Wheat**	Export	Durban	0.0%	0.2%	100.0%	100.0%	100.0%	-	29	29
FDM10050	**Wheat**	Import	Cape Town	1.0%	0.5%	0.5%	0.3%	0.3%	128 894	417	129 310
FDM10050	**Wheat**	Import	Durban	0.3%	0.2%	0.1%	0.1%	0.1%	1 452 972	899	1 453 871
FDM10050	**Wheat**	Import	Port Elizabeth	1.5%	2.2%	5.4%	2.1%	1.2%	94 005	1 098	95 103
FDM10060	**Soya beans**	Export	Durban	0.0%	2.2%	22.2%	100.0%	100.0%	-	459	459
FDM10060	**Soya beans**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 271	1 271
FDM10060	**Soya beans**	Import	Durban	83.2%	55.9%	17.0%	53.5%	1.9%	61 706	1 164	62 869
FDM10060	**Soya beans**	Import	Port Elizabeth	43.2%	100.0%	100.0%	0.3%	1.3%	7 770	104	7 873
FDM10070	**Rice**	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	1	-	1

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM10070	**Rice**	Export	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM10070	**Rice**	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM10070	**Rice**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	2	162 922	162 924
FDM10070	**Rice**	Import	Durban	25.0%	21.7%	33.5%	28.9%	39.4%	576 680	375 350	952 030
FDM10070	**Rice**	Import	Port Elizabeth	100.0%	25.8%	100.0%	100.0%	100.0%	-	29 148	29 148
FDM10080	**Vegetables**	Export	Cape Town	98.8%	99.8%	84.7%	91.4%	99.3%	74	10 543	10 617
FDM10080	**Vegetables**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	4 669	4 669
FDM10080	**Vegetables**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	179	179
FDM10080	**Vegetables**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	12 783	12 783
FDM10080	**Vegetables**	Import	Durban	102.2%	96.2%	99.4%	100.0%	100.0%	-	50 129	50 129
FDM10080	**Vegetables**	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 275	1 275
FDM10090	**Potatoes**	Export	Cape Town	78.9%	98.9%	73.4%	72.1%	95.9%	148	3 413	3 561
FDM10090	**Potatoes**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 006	1 006
FDM10090	**Potatoes**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	619	619
FDM10090	**Potatoes**	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 685	1 685
FDM10090	**Potatoes**	Import	Port Elizabeth	100.0%	0.0%	0.0%	100.0%	100.0%	-	19	19
FDM10120	**Cotton**	Export	Cape Town	100.0%	0.0%	100.0%	0.0%	0.0%	-	-	-
FDM10120	**Cotton**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	20 687	20 687
FDM10120	**Cotton**	Export	Port Elizabeth	0.0%	0.0%	100.0%	0.0%	0.0%	-	-	-
FDM10120	**Cotton**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 042	1 042
FDM10120	**Cotton**	Import	Durban	92.8%	100.0%	100.0%	32.9%	13.4%	6 790	1 052	7 842
FDM10120	**Cotton**	Import	Port Elizabeth	0.0%	100.0%	100.0%	0.0%	0.0%	-	-	-
FDM10130	**Grapes**	Export	Cape Town	98.7%	100.0%	98.9%	96.6%	93.5%	17 020	244 802	261 822
FDM10130	**Grapes**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	2 374	2 374
FDM10130	**Grapes**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	2 564	2 564
FDM10130	**Grapes**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	98.9%	53	4 722	4 775
FDM10130	**Grapes**	Import	Durban	0.0%	100.0%	100.0%	100.0%	100.0%	-	804	804
FDM10130	**Grapes**	Import	Port Elizabeth	0.0%	100.0%	0.0%	0.0%	100.0%	-	53	53
FDM10140	**Subtropical Fruit**	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	43 262	43 262
FDM10140	**Subtropical Fruit**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	5 710	5 710
FDM10140	**Subtropical Fruit**	Export	Port Elizabeth	100.0%	100.0%	100.0%	0.0%	100.0%	-	247	247

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM10140	**Subtropical Fruit**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	2 934	2 934
FDM10140	**Subtropical Fruit**	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 360	1 360
FDM10140	**Subtropical Fruit**	Import	Port Elizabeth	0.0%	100.0%	100.0%	100.0%	100.0%	-	210	210
FDM10150	**Citrus**	Export	Cape Town	75.7%	80.5%	85.3%	85.3%	86.9%	45 415	302 067	347 482
FDM10150	**Citrus**	Export	Durban	69.2%	79.4%	84.4%	85.1%	81.7%	170 644	759 900	930 544
FDM10150	**Citrus**	Export	Port Elizabeth	83.2%	86.3%	90.6%	92.5%	93.2%	23 357	320 945	344 302
FDM10150	**Citrus**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	0	3 935	3 935
FDM10150	**Citrus**	Import	Durban	100.0%	100.0%	88.1%	100.0%	30.0%	1 017	437	1 454
FDM10150	**Citrus**	Import	Port Elizabeth	0.0%	100.0%	100.0%	100.0%	100.0%	-	166	166
FDM10160	**Deciduous Fruit**	Export	Cape Town	96.2%	95.7%	96.6%	98.2%	99.6%	2 299	515 769	518 069
FDM10160	**Deciduous Fruit**	Export	Durban	100.0%	100.0%	98.7%	100.0%	100.0%	-	4 290	4 290
FDM10160	**Deciduous Fruit**	Export	Port Elizabeth	99.5%	97.4%	95.3%	99.7%	100.0%	-	53 682	53 682
FDM10160	**Deciduous Fruit**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	8 452	8 452
FDM10160	**Deciduous Fruit**	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 290	1 290
FDM10160	**Deciduous Fruit**	Import	Port Elizabeth	0.0%	100.0%	0.0%	0.0%	100.0%	-	69	69
FDM10170	**Milk (bulk)**	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	100.0%	-	400	400
FDM10180	**Eggs (poultry)**	Export	Cape Town	100.0%	100.0%	100.0%	0.0%	100.0%	-	42	42
FDM10180	**Eggs (poultry)**	Import	Cape Town	0.0%	100.0%	100.0%	100.0%	100.0%	-	57	57
FDM10180	**Eggs (poultry)**	Import	Durban	0.0%	100.0%	100.0%	100.0%	100.0%	-	88	88
FDM10180	**Eggs (poultry)**	Import	Port Elizabeth	0.0%	0.0%	100.0%	0.0%	0.0%	-	-	-
FDM10190	**Fish and seafood**	Export	Cape Town	77.4%	72.6%	81.1%	72.0%	92.9%	7 985	104 807	112 792
FDM10190	**Fish and seafood**	Export	Durban	94.3%	97.1%	96.3%	88.6%	90.4%	452	4 254	4 705
FDM10190	**Fish and seafood**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	8 656	8 656
FDM10190	**Fish and seafood**	Import	Cape Town	42.1%	40.4%	30.7%	41.4%	72.1%	28 090	72 533	100 623
FDM10190	**Fish and seafood**	Import	Durban	68.3%	88.6%	82.2%	79.7%	78.5%	5 832	21 346	27 178
FDM10190	**Fish and seafood**	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	379	379
FDM10200	**Other Agriculture**	Export	Cape Town	92.0%	70.9%	94.0%	99.0%	100.0%	7	13 893	13 900
FDM10200	**Other Agriculture**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	183 676	183 676
FDM10200	**Other Agriculture**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	53.5%	15 000	17 270	32 270
FDM10200	**Other Agriculture**	Import	Cape Town	20.6%	100.0%	50.8%	100.0%	100.0%	-	18 382	18 382
FDM10200	**Other Agriculture**	Import	Durban	33.9%	79.3%	93.1%	79.3%	96.3%	3 035	78 075	81 110

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM10200	**Other Agriculture**	Import	Port Elizabeth	24.3%	43.9%	45.9%	30.0%	15.3%	30 007	5 415	35 422
FDM20010	**Coal Mining Exports**	Export	Cape Town	0.0%	0.0%	100.0%	0.0%	0.0%	1	-	1
FDM20010	**Coal Mining Exports**	Export	Durban	2.3%	2.4%	2.8%	2.4%	2.7%	474 622	13 006	487 628
FDM20010	**Coal Mining Exports**	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	100.0%	-	553	553
FDM20010	**Coal Mining Exports**	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	395 108	-	395 108
FDM20020	**Coal Mining Domestic**	Import	Cape Town	100.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20020	**Coal Mining Domestic**	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	117	117
FDM20020	**Coal Mining Domestic**	Import	Port Elizabeth	100.0%	0.0%	100.0%	0.0%	0.0%	-	-	-
FDM20050	**Coal Mining Fly Ash**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 219	1 219
FDM20050	**Coal Mining Fly Ash**	Import	Cape Town	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20050	**Coal Mining Fly Ash**	Import	Durban	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20060	**Crude oil**	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20060	**Crude oil**	Export	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20060	**Crude oil**	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	187 083	-	187 083
FDM20060	**Crude oil**	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20070	**Iron Ore Exports**	Export	Cape Town	0.0%	0.0%	100.0%	100.0%	100.0%	-	1 472	1 472
FDM20070	**Iron Ore Exports**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	24 152	24 152
FDM20070	**Iron Ore Exports**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	5 618	5 618
FDM20070	**Iron Ore Exports**	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20080	**Iron Ore Domestic**	Import	Cape Town	100.0%	100.0%	0.0%	0.0%	100.0%	-	24	24
FDM20080	**Iron Ore Domestic**	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	550	550
FDM20090	**Precious metal ore**	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	100.0%	-	18	18
FDM20090	**Precious metal ore**	Export	Durban	0.0%	0.0%	0.0%	100.0%	100.0%	-	204	204
FDM20090	**Precious metal ore**	Import	Durban	0.0%	0.0%	100.0%	100.0%	100.0%	-	61	61
FDM20100	**Precious metals and precious stones (Refined)**	Export	Cape Town	0.0%	0.0%	0.0%	100.0%	100.0%	-	176	176
FDM20100	**Precious metals and precious stones (Refined)**	Export	Durban	0.0%	0.0%	0.0%	100.0%	100.0%	-	116	116
FDM20100	**Precious metals and precious stones (Refined)**	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	100.0%	-	103	103
FDM20110	**Magnetite**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 509	1 509
FDM20110	**Magnetite**	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM20120	**Chrome**	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	8 442	8 442
FDM20120	**Chrome**	Export	Durban	98.2%	94.0%	91.5%	86.9%	76.6%	570 572	1 870 027	2 440 599
FDM20120	**Chrome**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	308 952	308 952
FDM20120	**Chrome**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	183	183
FDM20120	**Chrome**	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 101	1 101
FDM20120	**Chrome**	Import	Port Elizabeth	100.0%	0.0%	0.0%	0.0%	100.0%	-	85	85
FDM20130	**Copper**	Export	Cape Town	97.8%	100.0%	99.5%	96.6%	100.0%	0	3 482	3 482
FDM20130	**Copper**	Export	Durban	68.5%	74.9%	72.4%	84.5%	80.1%	75 971	306 217	382 189
FDM20130	**Copper**	Export	Port Elizabeth	100.0%	0.0%	100.0%	100.0%	100.0%	-	19	19
FDM20130	**Copper**	Import	Cape Town	100.0%	99.4%	0.0%	100.0%	100.0%	-	346	346
FDM20130	**Copper**	Import	Durban	74.1%	7.7%	4.7%	76.6%	55.4%	377	468	845
FDM20130	**Copper**	Import	Port Elizabeth	100.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20140	**Manganese Exports**	Export	Cape Town	0.0%	0.0%	100.0%	0.0%	100.0%	-	20 997	20 997
FDM20140	**Manganese Exports**	Export	Durban	28.1%	4.5%	4.6%	4.1%	7.4%	3 107 219	248 198	3 355 417
FDM20140	**Manganese Exports**	Export	Port Elizabeth	2.4%	1.6%	2.9%	7.2%	7.3%	-	490 936	490 936
FDM20140	**Manganese Exports**	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	22 001	-	22 001
FDM20140	**Manganese Exports**	Import	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20150	**Manganese Domestic**	Import	Durban	100.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20150	**Manganese Domestic**	Import	Port Elizabeth	100.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20160	**Titanium slag**	Export	Cape Town	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20160	**Titanium slag**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	411	411
FDM20160	**Titanium slag**	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 023	1 023
FDM20160	**Titanium slag**	Import	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20170	**Rutile**	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 932	1 932
FDM20170	**Rutile**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	2 768	2 768
FDM20170	**Rutile**	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20180	**Ilmenite (Titanium ore)**	Export	Durban	0.0%	0.0%	100.0%	0.0%	0.0%	-	-	-
FDM20190	**Alumina**	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20190	**Alumina**	Export	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20190	**Alumina**	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	100.0%	-	333	333
FDM20190	**Alumina**	Import	Durban	0.4%	0.0%	0.0%	0.0%	0.0%	15 003	-	15 003

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM20200	**Gypsum**	Export	Durban	0.0%	0.0%	0.0%	0.0%	100.0%	-	33	33
FDM20200	**Gypsum**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	872	872
FDM20200	**Gypsum**	Import	Durban	1.1%	100.0%	19.2%	100.0%	1.0%	102 084	1 012	103 096
FDM20200	**Gypsum**	Import	Port Elizabeth	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20210	**Zircon**	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	23 415	23 415
FDM20210	**Zircon**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	31 670	31 670
FDM20210	**Zircon**	Export	Port Elizabeth	0.0%	0.0%	100.0%	0.0%	0.0%	-	-	-
FDM20210	**Zircon**	Import	Durban	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20210	**Zircon**	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	2.3%	197	5	201
FDM20220	**Stone**	Export	Cape Town	73.4%	50.6%	57.6%	56.4%	78.0%	3 606	12 797	16 403
FDM20220	**Stone**	Export	Durban	56.9%	96.6%	100.0%	100.0%	100.0%	-	26 299	26 299
FDM20220	**Stone**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	88	88
FDM20220	**Stone**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	0	10 189	10 189
FDM20220	**Stone**	Import	Durban	97.5%	94.5%	95.2%	100.0%	100.0%	-	28 388	28 388
FDM20220	**Stone**	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 511	1 511
FDM20230	**Granite**	Export	Cape Town	91.5%	100.0%	100.0%	100.0%	98.9%	278	25 905	26 183
FDM20230	**Granite**	Export	Durban	60.4%	54.9%	72.5%	99.5%	100.0%	-	27 333	27 333
FDM20230	**Granite**	Export	Port Elizabeth	0.0%	0.0%	100.0%	0.0%	0.0%	-	-	-
FDM20230	**Granite**	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	2 718	2 718
FDM20230	**Granite**	Import	Durban	98.8%	100.0%	100.0%	100.0%	100.0%	-	6 702	6 702
FDM20230	**Granite**	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	24	24
FDM20240	**Limestone**	Export	Cape Town	100.0%	100.0%	100.0%	9.5%	0.0%	112	-	112
FDM20240	**Limestone**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 000	1 000
FDM20240	**Limestone**	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20240	**Limestone**	Import	Cape Town	100.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20240	**Limestone**	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	2 550	2 550
FDM20240	**Limestone**	Import	Port Elizabeth	100.0%	100.0%	100.0%	0.0%	0.0%	-	-	-
FDM20250	**Rock Phosphate**	Import	Cape Town	100.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20250	**Rock Phosphate**	Import	Durban	100.0%	100.0%	100.0%	0.0%	0.0%	-	-	-
FDM20250	**Rock Phosphate**	Import	Port Elizabeth	0.0%	100.0%	0.0%	0.0%	0.0%	-	-	-
FDM20270	**Fluorspar**	Export	Durban	0.0%	0.0%	0.0%	0.2%	0.0%	171 913	-	171 913

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM20270	Fluorspar	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM20280	Salt	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	16 183	16 183
FDM20280	Salt	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	20 662	20 662
FDM20280	Salt	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	174	174
FDM20280	Salt	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	3 899	3 899
FDM20280	Salt	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	27 713	27 713
FDM20280	Salt	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	6 200	6 200
FDM20290	Other Non-Ferrous Metal Mining	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	667	667
FDM20290	Other Non-Ferrous Metal Mining	Export	Durban	100.0%	100.0%	88.0%	93.2%	92.4%	19 200	232 974	252 174
FDM20290	Other Non-Ferrous Metal Mining	Export	Port Elizabeth	100.0%	0.0%	0.0%	0.0%	100.0%	-	33	33
FDM20290	Other Non-Ferrous Metal Mining	Import	Cape Town	100.0%	0.0%	0.0%	99.0%	100.0%	-	225	225
FDM20290	Other Non-Ferrous Metal Mining	Import	Durban	99.9%	100.0%	100.0%	100.0%	100.0%	-	8 462	8 462
FDM20290	Other Non-Ferrous Metal Mining	Import	Port Elizabeth	0.0%	0.0%	100.0%	100.0%	100.0%	-	156	156
FDM20300	Other Mining	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	92.6%	4 000	50 015	54 015
FDM20300	Other Mining	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	831 751	831 751
FDM20300	Other Mining	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	187 383	187 383
FDM20300	Other Mining	Import	Cape Town	24.5%	100.0%	92.2%	93.9%	10.8%	36 266	4 384	40 650
FDM20300	Other Mining	Import	Durban	19.5%	30.2%	26.9%	29.0%	16.8%	175 529	35 439	210 968
FDM20300	Other Mining	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	850	850
FDM30010	Processed Foods	Export	Cape Town	100.0%	100.0%	100.0%	99.9%	99.9%	155	303 237	303 392
FDM30010	Processed Foods	Export	Durban	71.5%	72.5%	75.0%	60.6%	42.7%	465 961	347 475	813 436
FDM30010	Processed Foods	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	26 237	26 237
FDM30010	Processed Foods	Import	Cape Town	67.5%	72.6%	60.8%	73.3%	61.7%	191 259	308 012	499 271
FDM30010	Processed Foods	Import	Durban	49.4%	56.1%	48.0%	55.8%	48.5%	951 620	896 690	1 848 310
FDM30010	Processed Foods	Import	Port Elizabeth	97.1%	91.6%	80.4%	90.4%	83.6%	15 994	81 275	97 269
FDM30020	Slaughtered animal meat	Export	Cape Town	98.8%	99.3%	99.6%	99.9%	99.9%	10	10 970	10 980
FDM30020	Slaughtered animal meat	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	4 267	4 267
FDM30020	Slaughtered animal meat	Export	Port Elizabeth	0.0%	100.0%	100.0%	100.0%	100.0%	-	1 383	1 383

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM30020	Slaughtered animal meat	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	92 829	92 829
FDM30020	Slaughtered animal meat	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	292 352	292 352
FDM30020	Slaughtered animal meat	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	7 882	7 882
FDM30030	Soya bean products	Export	Durban	0.0%	33.4%	100.0%	100.0%	100.0%	-	9 457	9 457
FDM30030	Soya bean products	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	181 450	-	181 450
FDM30030	Soya bean products	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	240 063	-	240 063
FDM30030	Soya bean products	Import	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	31 153	-	31 153
FDM30040	Animal feed	Export	Cape Town	99.9%	99.9%	99.7%	98.7%	99.9%	21	31 636	31 657
FDM30040	Animal feed	Export	Durban	0.0%	0.0%	0.0%	0.0%	100.0%	-	456	456
FDM30040	Animal feed	Import	Cape Town	62.6%	25.3%	29.6%	46.7%	96.8%	136	4 075	4 211
FDM30040	Animal feed	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	792	792
FDM30040	Animal feed	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 088	1 088
FDM30050	Beverages	Export	Cape Town	100.0%	100.0%	99.1%	98.3%	100.0%	37	720 019	720 055
FDM30050	Beverages	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	47 849	47 849
FDM30050	Beverages	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	6 430	6 430
FDM30050	Beverages	Import	Cape Town	100.0%	100.0%	97.8%	100.1%	100.0%	-	61 676	61 676
FDM30050	Beverages	Import	Durban	80.4%	56.3%	65.8%	77.8%	72.4%	56 277	147 793	204 070
FDM30050	Beverages	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 160	1 160
FDM30060	Tobacco Products	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	556	556
FDM30060	Tobacco Products	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	79 590	79 590
FDM30060	Tobacco Products	Export	Port Elizabeth	100.0%	100.0%	0.0%	0.0%	100.0%	-	3 111	3 111
FDM30060	Tobacco Products	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	343	343
FDM30060	Tobacco Products	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	19 442	19 442
FDM30060	Tobacco Products	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	19	19
FDM30070	Textile Products	Export	Cape Town	99.9%	99.9%	99.9%	99.9%	99.9%	28	19 185	19 213
FDM30070	Textile Products	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	137 113	137 113
FDM30070	Textile Products	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	52 995	52 995
FDM30070	Textile Products	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	2	159 832	159 834
FDM30070	Textile Products	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	20	519 716	519 735
FDM30070	Textile Products	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	35 498	35 498
FDM30080	Wood timber and products	Export	Cape Town	98.3%	96.7%	93.8%	98.6%	97.4%	517	19 735	20 252

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM30080	Wood timber and products	Export	Durban	96.6%	97.1%	97.2%	98.9%	90.9%	9 844	97 820	107 664
FDM30080	Wood timber and products	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	27 062	27 062
FDM30080	Wood timber and products	Import	Cape Town	90.4%	80.2%	83.8%	94.1%	92.0%	8 399	96 881	105 281
FDM30080	Wood timber and products	Import	Durban	95.0%	94.1%	95.8%	97.0%	98.5%	2 497	166 011	168 508
FDM30080	Wood timber and products	Import	Port Elizabeth	99.9%	100.0%	100.0%	100.0%	100.0%	-	15 438	15 438
FDM30090	Wood chips	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM30090	Wood chips	Export	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	547 380	-	547 380
FDM30090	Wood chips	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM30100	Paper	Export	Cape Town	99.9%	100.0%	100.0%	100.0%	100.0%	3	14 604	14 607
FDM30100	Paper	Export	Durban	100.0%	99.9%	99.6%	100.0%	99.5%	1 627	294 794	296 421
FDM30100	Paper	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	11 684	11 684
FDM30100	Paper	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	7	168 526	168 533
FDM30100	Paper	Import	Durban	99.9%	100.0%	100.0%	100.0%	99.9%	356	471 508	471 865
FDM30100	Paper	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	20 051	20 051
FDM30110	Pulp of wood and paper	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	100.0%	-	58	58
FDM30110	Pulp of wood and paper	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	461 620	461 620
FDM30110	Pulp of wood and paper	Export	Port Elizabeth	0.0%	0.0%	0.0%	100.0%	0.0%	-	-	-
FDM30110	Pulp of wood and paper	Import	Cape Town	0.0%	100.0%	100.0%	100.0%	100.0%	-	5 305	5 305
FDM30110	Pulp of wood and paper	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	93 785	93 785
FDM30110	Pulp of wood and paper	Import	Port Elizabeth	0.0%	100.0%	100.0%	100.0%	100.0%	-	1 605	1 605
FDM30120	Recycled paper	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	100.0%	-	18 796	18 796
FDM30120	Recycled paper	Export	Durban	0.0%	0.0%	100.0%	0.0%	100.0%	-	8 831	8 831
FDM30120	Recycled paper	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	100.0%	-	3 764	3 764
FDM30120	Recycled paper	Import	Cape Town	0.0%	100.0%	100.0%	0.0%	100.0%	-	1 010	1 010
FDM30120	Recycled paper	Import	Durban	0.0%	0.0%	100.0%	100.0%	100.0%	-	16	16
FDM30130	Printing and Publishing	Export	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	744	744
FDM30130	Printing and Publishing	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 451	1 451
FDM30130	Printing and Publishing	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	100.0%	-	525	525
FDM30130	Printing and Publishing	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	15 071	15 071
FDM30130	Printing and Publishing	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	16 451	16 451
FDM30130	Printing and Publishing	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	2 463	2 463

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM30140	**Petrol**	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	558 940	56	558 996
FDM30140	**Petrol**	Export	Durban	0.8%	0.0%	0.3%	0.4%	0.0%	424 359	208	424 568
FDM30140	**Petrol**	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-
FDM30140	**Petrol**	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	718 907	68	718 975
FDM30140	**Petrol**	Import	Durban	0.2%	0.0%	0.1%	0.1%	0.2%	793 259	1 242	794 501
FDM30140	**Petrol**	Import	Port Elizabeth	0.0%	0.0%	0.0%	0.1%	0.1%	330 584	254	330 838
FDM30150	**Diesel**	Export	Cape Town	0.0%	0.0%	0.1%	0.0%	0.0%	132 164	30	132 194
FDM30150	**Diesel**	Export	Durban	0.0%	0.0%	0.1%	0.1%	0.0%	754 289	296	754 585
FDM30150	**Diesel**	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	100.0%	-	34	34
FDM30150	**Diesel**	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	520 242	-	520 242
FDM30150	**Diesel**	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	3 452 650	-	3 452 650
FDM30150	**Diesel**	Import	Port Elizabeth	0.9%	0.0%	0.0%	0.0%	0.0%	370 093	-	370 093
FDM30160	**Jet fuel**	Export	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	12 408	-	12 408
FDM30160	**Jet fuel**	Export	Durban	0.3%	0.1%	0.0%	0.0%	0.7%	89 184	595	89 779
FDM30160	**Jet fuel**	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	0.0%	49 657	-	49 657
FDM30160	**Jet fuel**	Import	Durban	0.0%	0.0%	0.0%	0.0%	0.0%	312 557	-	312 557
FDM30160	**Jet fuel**	Import	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	0.0%	26 540	-	26 540
FDM30170	**Other Petroleum Products**	Export	Cape Town	21.6%	1.4%	84.6%	93.9%	-9.7%	-20 181	1 788	-18 393
FDM30170	**Other Petroleum Products**	Export	Durban	6.3%	9.8%	5.7%	4.6%	6.5%	908 328	63 363	971 691
FDM30170	**Other Petroleum Products**	Export	Port Elizabeth	0.0%	100.0%	100.0%	100.0%	100.0%	-	37	37
FDM30170	**Other Petroleum Products**	Import	Cape Town	25.1%	9.4%	2.9%	3.8%	3.9%	78 081	3 207	81 288
FDM30170	**Other Petroleum Products**	Import	Durban	24.6%	17.0%	25.1%	22.5%	19.0%	346 414	81 107	427 522
FDM30170	**Other Petroleum Products**	Import	Port Elizabeth	0.3%	0.5%	1.7%	2.9%	2.5%	149 410	3 854	153 264
FDM30180	**LNG and Methane Rich Gas**	Import	Cape Town	0.0%	0.0%	0.0%	0.0%	100.0%	-	1 283	1 283
FDM30190	**Chemicals**	Export	Cape Town	99.6%	99.6%	99.6%	99.7%	98.4%	397	23 899	24 296
FDM30190	**Chemicals**	Export	Durban	61.4%	67.1%	65.3%	54.2%	53.7%	481 722	559 168	1 040 889
FDM30190	**Chemicals**	Export	Port Elizabeth	100.0%	100.0%	100.0%	99.9%	100.0%	-	2 587	2 587
FDM30190	**Chemicals**	Import	Cape Town	74.0%	84.5%	85.5%	87.7%	95.1%	10 097	194 317	204 414
FDM30190	**Chemicals**	Import	Durban	68.8%	63.1%	66.4%	68.3%	64.0%	819 559	1 459 917	2 279 476
FDM30190	**Chemicals**	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	86 557	86 557
FDM30200	**Fertilizer**	Export	Cape Town	96.6%	99.0%	97.6%	51.5%	96.9%	61	1 905	1 966

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM30200	Fertilizer	Export	Durban	80.8%	70.1%	79.7%	95.9%	99.3%	60	8 255	8 315
FDM30200	Fertilizer	Export	Port Elizabeth	0.0%	0.0%	0.0%	0.0%	100.0%	-	40	40
FDM30200	Fertilizer	Import	Cape Town	9.6%	8.7%	8.2%	8.3%	13.4%	201 828	31 140	232 967
FDM30200	Fertilizer	Import	Durban	6.5%	6.9%	6.1%	4.3%	6.5%	1 061 040	73 347	1 134 387
FDM30200	Fertilizer	Import	Port Elizabeth	16.3%	28.7%	8.5%	10.8%	4.9%	68 588	3 538	72 126
FDM30210	Pharmaceutical Products	Export	Cape Town	99.7%	100.0%	100.0%	100.0%	99.9%	5	3 440	3 445
FDM30210	Pharmaceutical Products	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	33 004	33 004
FDM30210	Pharmaceutical Products	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	3 478	3 478
FDM30210	Pharmaceutical Products	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	20 747	20 747
FDM30210	Pharmaceutical Products	Import	Durban	100.0%	100.0%	100.0%	100.0%	99.9%	186	183 856	184 042
FDM30210	Pharmaceutical Products	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	12 587	12 587
FDM30220	Bricks	Export	Cape Town	100.0%	0.0%	99.6%	100.0%	0.0%	51	-	51
FDM30220	Bricks	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 649	1 649
FDM30220	Bricks	Import	Cape Town	100.0%	100.0%	100.0%	100.0%	100.0%	-	4 289	4 289
FDM30220	Bricks	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	28 129	28 129
FDM30220	Bricks	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	1 999	1 999
FDM30230	Cement	Export	Cape Town	0.0%	1.4%	8.9%	0.0%	0.0%	66 259	31	66 290
FDM30230	Cement	Export	Durban	95.7%	26.0%	100.0%	100.0%	100.0%	-	3 443	3 443
FDM30230	Cement	Import	Cape Town	96.2%	100.0%	78.1%	29.7%	7.0%	232 703	17 586	250 289
FDM30230	Cement	Import	Durban	100.0%	94.1%	39.7%	7.1%	4.5%	824 802	38 759	863 561
FDM30230	Cement	Import	Port Elizabeth	100.0%	100.0%	60.2%	16.0%	5.9%	257 489	16 273	273 763
FDM30240	Iron & Steel	Export	Cape Town	80.1%	95.1%	86.7%	91.1%	93.0%	2 167	28 847	31 014
FDM30240	Iron & Steel	Export	Durban	38.0%	49.6%	54.1%	66.5%	59.6%	386 771	570 639	957 410
FDM30240	Iron & Steel	Export	Port Elizabeth	35.7%	100.0%	25.7%	40.7%	99.9%	12	16 341	16 353
FDM30240	Iron & Steel	Import	Cape Town	69.1%	84.9%	76.8%	87.9%	90.6%	8 764	84 097	92 860
FDM30240	Iron & Steel	Import	Durban	33.8%	26.2%	33.8%	29.8%	34.7%	731 073	388 356	1 119 429
FDM30240	Iron & Steel	Import	Port Elizabeth	38.1%	33.9%	26.2%	29.2%	23.5%	82 699	25 411	108 110
FDM30250	Ferrochrome	Export	Cape Town	0.0%	100.0%	0.0%	100.0%	100.0%	-	203	203
FDM30250	Ferrochrome	Export	Durban	100.0%	100.0%	93.6%	100.0%	100.0%	-	108 475	108 475
FDM30250	Ferrochrome	Import	Durban	100.0%	100.0%	100.0%	0.0%	100.0%	-	15	15
FDM30260	Ferromanganese	Export	Cape Town	0.0%	0.0%	100.0%	0.0%	0.0%	-	-	-

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM30260	Ferromanganese	Export	Durban	88.4%	100.0%	93.4%	102.4%	100.0%	-	134 147	134 147
FDM30260	Ferromanganese	Export	Port Elizabeth	0.0%	100.0%	100.0%	100.0%	0.0%	-	-	-
FDM30260	Ferromanganese	Import	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	-	31	31
FDM30270	Scrap metals	Export	Cape Town	100.0%	94.9%	100.0%	100.0%	100.0%	-	233 814	233 814
FDM30270	Scrap metals	Export	Durban	87.2%	86.7%	87.7%	85.9%	84.0%	237 968	1 248 078	1 486 046
FDM30270	Scrap metals	Export	Port Elizabeth	74.1%	69.1%	66.6%	69.9%	76.8%	43 625	144 696	188 321
FDM30270	Scrap metals	Import	Cape Town	53.4%	0.0%	100.0%	23.7%	45.1%	385	317	702
FDM30270	Scrap metals	Import	Durban	-1.0%	79.7%	16.1%	100.0%	100.0%	-	2 862	2 862
FDM30270	Scrap metals	Import	Port Elizabeth	100.0%	100.0%	0.0%	0.0%	100.0%	-	18	18
FDM30280	Metal products, machinery and electronic equipment	Export	Cape Town	93.3%	84.4%	88.8%	89.2%	93.2%	2 641	36 230	38 871
FDM30280	Metal products, machinery and electronic equipment	Export	Durban	88.4%	90.8%	91.5%	91.8%	82.5%	27 614	129 734	157 348
FDM30280	Metal products, machinery and electronic equipment	Export	Port Elizabeth	96.0%	90.0%	76.3%	95.4%	85.5%	2 763	16 271	19 033
FDM30280	Metal products, machinery and electronic equipment	Import	Cape Town	93.8%	94.1%	97.7%	98.5%	98.0%	3 550	171 410	174 959
FDM30280	Metal products, machinery and electronic equipment	Import	Durban	88.1%	86.7%	89.6%	86.2%	91.7%	81 881	902 690	984 571
FDM30280	Metal products, machinery and electronic equipment	Import	Port Elizabeth	94.8%	97.5%	88.8%	64.5%	66.9%	50 022	101 322	151 344
FDM30290	Motor vehicles and trucks	Export	Cape Town	66.8%	64.5%	55.6%	43.9%	31.3%	1 181	538	1 719
FDM30290	Motor vehicles and trucks	Export	Durban	0.6%	0.3%	0.3%	0.3%	0.3%	1 907 003	5 757	1 912 760
FDM30290	Motor vehicles and trucks	Export	Port Elizabeth	0.3%	0.4%	0.6%	0.5%	0.0%	467 690	113	467 803
FDM30290	Motor vehicles and trucks	Import	Cape Town	11.1%	54.8%	50.5%	14.9%	89.7%	345	2 987	3 332
FDM30290	Motor vehicles and trucks	Import	Durban	10.0%	9.3%	8.1%	5.8%	5.0%	2 536 937	133 188	2 670 125
FDM30290	Motor vehicles and trucks	Import	Port Elizabeth	2.7%	1.8%	3.8%	0.8%	0.9%	615 549	5 484	621 033
FDM30300	Motor Vehicle Parts & Accessories	Export	Cape Town	99.9%	99.9%	100.0%	100.0%	100.0%	7	61 794	61 801
FDM30300	Motor Vehicle Parts & Accessories	Export	Durban	98.2%	97.4%	97.5%	96.1%	91.8%	4 425	49 506	53 931
FDM30300	Motor Vehicle Parts & Accessories	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	99.7%	206	70 362	70 568
FDM30300	Motor Vehicle Parts & Accessories	Import	Cape Town	96.9%	95.5%	82.4%	91.5%	93.6%	2 654	39 075	41 730

FDM #	FDM Name	Import/Export	Port	2010	2011	2012	2013	2014	Bulk Tonnes	TEU tonnes	2014 Total
FDM30300	**Motor Vehicle Parts & Accessories**	Import	Durban	97.7%	94.5%	92.4%	95.5%	94.0%	34 698	547 364	582 062
FDM30300	**Motor Vehicle Parts & Accessories**	Import	Port Elizabeth	100.0%	100.0%	100.0%	99.8%	100.0%	4	294 237	294 241
FDM30310	**Transport Equipment**	Export	Cape Town	69.0%	65.9%	17.4%	33.7%	32.7%	6 640	3 233	9 873
FDM30310	**Transport Equipment**	Export	Durban	54.3%	82.0%	43.4%	72.0%	73.4%	2 213	6 097	8 310
FDM30310	**Transport Equipment**	Export	Port Elizabeth	95.8%	6.2%	69.9%	19.8%	10.0%	2 999	333	3 333
FDM30310	**Transport Equipment**	Import	Cape Town	94.0%	70.9%	28.7%	60.9%	62.3%	6 235	10 283	16 518
FDM30310	**Transport Equipment**	Import	Durban	77.6%	86.6%	80.0%	85.3%	82.3%	6 964	32 451	39 415
FDM30310	**Transport Equipment**	Import	Port Elizabeth	93.2%	90.5%	73.3%	63.5%	65.1%	2 033	3 791	5 824
FDM30320	**Other Manufacturing Industries**	Export	Cape Town	99.9%	99.9%	99.4%	99.8%	97.7%	1 194	49 629	50 823
FDM30320	**Other Manufacturing Industries**	Export	Durban	100.0%	99.9%	100.0%	99.8%	99.9%	508	354 926	355 433
FDM30320	**Other Manufacturing Industries**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	27 663	27 663
FDM30320	**Other Manufacturing Industries**	Import	Cape Town	99.7%	99.5%	99.6%	99.9%	99.8%	797	367 301	368 098
FDM30320	**Other Manufacturing Industries**	Import	Durban	100.0%	99.9%	99.9%	99.8%	99.9%	1 671	1 436 840	1 438 511
FDM30320	**Other Manufacturing Industries**	Import	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	142 174	142 174
FDM30330	**Non-Ferrous Metal Products**	Export	Cape Town	99.8%	100.0%	100.0%	99.9%	100.0%	2	25 136	25 138
FDM30330	**Non-Ferrous Metal Products**	Export	Durban	100.0%	100.0%	100.0%	100.0%	100.0%	1	594 315	594 317
FDM30330	**Non-Ferrous Metal Products**	Export	Port Elizabeth	100.0%	100.0%	100.0%	100.0%	100.0%	-	3 626	3 626
FDM30330	**Non-Ferrous Metal Products**	Import	Cape Town	100.0%	99.8%	99.9%	99.9%	100.0%	12	43 997	44 010
FDM30330	**Non-Ferrous Metal Products**	Import	Durban	99.8%	99.9%	98.7%	100.0%	99.6%	935	226 457	227 392
FDM30330	**Non-Ferrous Metal Products**	Import	Port Elizabeth	100.0%	100.0%	100.0%	99.4%	100.0%	-	43 838	43 838

APPENDIX C – WEIGHT PER CONTAINER PHYSICAL TYPE INPUT TABLES

The shipping line data provided some extent of the weight per container type for each of the commodities used within the Freight Demand Model (FDM), per port, per year for imports and exports.

To add the full complexity of this takes 1494 lines of data and would take several pages. For the convenience of the reader only an extraction of this level of detail is provided for The Port of Durban's import and export weight per twenty foot and forty foot containers per commodity.

The data fields included in this Appendix on the next page are:

- Direction IMP = Import or EXP = Export
- FDM_Name FDM Commodity Name
- (Port This data was filtered for the Port of Durban only)
- **LK_00**: Base year for input values
- **LK_01**: Current model year
- **LK_02**: Forecast year 1
- **LK_03**: Forecast year 2
- **LK_04**: Forecast year 3
- **LK_05**: Forecast year 4
- **LK_06**: Forecast year 5
- **LK_11**: Forecast year 10
- **LK_16**: Forecast year 15
- **LK_31**: Forecast year 30

The values in these tables were applied according to the physical family types and had to be processed further per port in order to find the unique port parameter values. More data sources is required defining detailed container physical type in order to be able to provide detailed modelling parameter values for weight per container physical type at a port and commodity and direction level over the forecast horizon.

Direction	FDM_name	20 foot										40 foot									
		LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31	LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31
EXP	Barley	12.9	14.4	16.2	18.2	20.4	22.8	22.8	22.8	22.8	22.8	12.9	14.3	15.9	17.7	19.7	21.9	21.9	21.9	21.9	21.9
EXP	Grain Sorghum	19.9	20.3	20.8	21.3	21.8	22.3	22.3	22.3	22.3	22.3	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
EXP	Maize	18.3	19.2	20.1	21.0	21.9	23.0	23.0	23.0	23.0	23.0	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
EXP	Sunflower Seed	9.4	10.6	11.9	13.5	15.2	17.1	17.1	17.1	17.1	17.1	18.8	19.9	21.0	22.2	23.4	24.7	24.7	24.7	24.7	24.7
EXP	Wheat	7.5	9.3	11.5	14.3	17.7	21.9	21.9	21.9	21.9	21.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
EXP	Soya beans	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
EXP	Rice	18.4	19.6	20.8	22.2	23.6	25.1	25.1	25.1	25.1	25.1	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7
EXP	Vegetables	16.8	17.5	18.3	19.1	19.9	20.8	20.8	20.8	20.8	20.8	18.5	19.5	20.5	21.6	22.8	24.0	24.0	24.0	24.0	24.0
EXP	Potatoes	14.2	14.2	14.3	14.4	14.4	14.5	14.5	14.5	14.5	14.5	22.9	23.4	23.8	24.3	24.9	25.4	25.4	25.4	25.4	25.4
EXP	Cassava	11.4	11.7	12.1	12.4	12.7	13.1	13.1	13.1	13.1	13.1	11.4	11.7	12.1	12.4	12.7	13.1	13.1	13.1	13.1	13.1
EXP	Sugar cane	11.4	11.7	12.1	12.4	12.7	13.1	13.1	13.1	13.1	13.1	11.4	11.7	12.1	12.4	12.7	13.1	13.1	13.1	13.1	13.1
EXP	Cotton	11.1	12.2	13.4	14.8	16.3	17.9	17.9	17.9	17.9	17.9	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8
EXP	Grapes	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.3	8.3	8.3	18.1	18.4	18.7	19.1	19.4	19.8	19.8	19.8	19.8	19.8
EXP	Subtropical Fruit	16.0	16.1	16.1	16.2	16.3	16.3	16.3	16.3	16.3	16.3	18.2	18.2	18.3	18.4	18.5	18.5	18.5	18.5	18.5	18.5
EXP	Citrus	14.0	14.9	15.8	16.8	17.8	19.0	19.0	19.0	19.0	19.0	22.1	22.3	22.6	22.8	23.1	23.3	23.3	23.3	23.3	23.3
EXP	Deciduous Fruit	14.3	15.8	17.5	19.3	21.4	23.6	23.6	23.6	23.6	23.6	21.1	21.5	21.9	22.3	22.7	23.1	23.1	23.1	23.1	23.1
EXP	Milk (bulk)	15.5	16.2	16.9	17.7	18.5	19.3	19.3	19.3	19.3	19.3	15.5	16.2	16.9	17.7	18.5	19.3	19.3	19.3	19.3	19.3
EXP	Eggs (poultry)	8.4	8.9	9.4	9.9	10.5	11.0	11.0	11.0	11.0	11.0	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
EXP	Fish and seafood	14.5	14.6	14.7	14.7	14.8	14.8	14.8	14.8	14.8	14.8	25.1	25.2	25.3	25.4	25.5	25.6	25.6	25.6	25.6	25.6
EXP	Other Agriculture	17.1	17.1	17.2	17.3	17.3	17.4	17.4	17.4	17.4	17.4	18.2	18.3	18.4	18.5	18.5	18.6	18.6	18.6	18.6	18.6
EXP	Coal Mining Exports	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5
EXP	Coal Mining Domestic	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7
EXP	Coal Mining Powerstation	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7
EXP	Coal Mining Sasol	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7
EXP	Coal Mining Fly Ash	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3
EXP	Crude oil	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
EXP	Iron Ore Exports	27.3	27.4	27.5	27.6	27.8	27.9	27.9	27.9	27.9	27.9	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4
EXP	Iron Ore Domestic	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4
EXP	Precious metal ore	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
EXP	Precious metals and precious stones (Refined)	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2

Direction	FDM_name	20 foot										40 foot									
		LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31	LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31
EXP	Magnetite	25.3	25.3	25.3	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4
EXP	Chrome	25.4	25.5	25.5	25.5	25.6	25.6	25.6	25.6	25.6	25.6	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
EXP	Copper	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1
EXP	Manganese Exports	25.9	26.2	26.4	26.6	26.9	27.1	27.1	27.1	27.1	27.1	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8
EXP	Manganese Domestic	24.8	25.2	25.7	26.1	26.6	27.1	27.1	27.1	27.1	27.1	24.8	25.2	25.7	26.1	26.6	27.1	27.1	27.1	27.1	27.1
EXP	Titanium slag	15.5	16.4	17.3	18.3	19.3	20.4	20.4	20.4	20.4	20.4	16.6	17.8	19.2	20.6	22.2	23.8	23.8	23.8	23.8	23.8
EXP	Rutile	23.5	23.9	24.4	24.8	25.3	25.8	25.8	25.8	25.8	25.8	23.5	23.9	24.4	24.9	25.4	25.9	25.9	25.9	25.9	25.9
EXP	Ilmenite (Titanium ore)	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8
EXP	Alumina	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
EXP	Gypsum	21.5	21.8	22.2	22.5	22.9	23.3	23.3	23.3	23.3	23.3	21.5	21.7	21.9	22.0	22.2	22.4	22.4	22.4	22.4	22.4
EXP	Zircon	23.1	23.5	24.0	24.5	25.0	25.5	25.5	25.5	25.5	25.5	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3
EXP	Stone	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1	17.3	17.6	17.8	18.1	18.3	18.6	18.6	18.6	18.6	18.6
EXP	Granite	23.1	23.1	23.1	23.1	23.1	23.1	23.1	23.1	23.1	23.1	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
EXP	Limestone	17.4	18.2	19.0	19.8	20.6	21.5	21.5	21.5	21.5	21.5	17.4	18.2	19.2	20.2	21.2	22.3	22.3	22.3	22.3	22.3
EXP	Rock Phosphate	21.8	22.2	22.6	23.1	23.5	23.9	23.9	23.9	23.9	23.9	21.8	22.2	22.6	23.1	23.5	23.9	23.9	23.9	23.9	23.9
EXP	Sulphur	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
EXP	Fluorspar	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2
EXP	Salt	21.8	22.1	22.4	22.7	23.0	23.3	23.3	23.3	23.3	23.3	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
EXP	Other Non-Ferrous Metal Mining	23.6	23.8	24.0	24.3	24.5	24.7	24.7	24.7	24.7	24.7	24.7	24.9	25.2	25.4	25.7	25.9	25.9	25.9	25.9	25.9
EXP	Other Mining	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5
EXP	Processed Foods	19.5	19.7	19.9	20.1	20.3	20.5	20.5	20.5	20.5	20.5	19.5	19.7	19.9	20.0	20.2	20.4	20.4	20.4	20.4	20.4
EXP	Slaughtered animal meat	16.5	16.7	16.8	17.0	17.2	17.3	17.3	17.3	17.3	17.3	26.2	26.4	26.7	26.9	27.2	27.5	27.5	27.5	27.5	27.5
EXP	Soya bean products	22.3	22.5	22.7	22.9	23.2	23.4	23.4	23.4	23.4	23.4	20.9	21.1	21.3	21.5	21.7	21.9	21.9	21.9	21.9	21.9
EXP	Animal feed	17.1	17.3	17.4	17.6	17.8	18.0	18.0	18.0	18.0	18.0	17.1	17.3	17.4	17.6	17.8	18.0	18.0	18.0	18.0	18.0
EXP	Beverages	16.8	16.9	17.1	17.3	17.4	17.6	17.6	17.6	17.6	17.6	20.9	21.1	21.3	21.5	21.7	21.9	21.9	21.9	21.9	21.9
EXP	Tobacco Products	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
EXP	Textile Products	12.5	12.6	12.8	12.9	13.0	13.1	13.1	13.1	13.1	13.1	16.5	16.6	16.8	17.0	17.1	17.3	17.3	17.3	17.3	17.3
EXP	Wood timber and products	20.7	20.9	21.1	21.3	21.5	21.7	21.7	21.7	21.7	21.7	23.6	23.8	24.1	24.3	24.5	24.8	24.8	24.8	24.8	24.8
EXP	Wood chips	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
EXP	Paper	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9

Direction	FDM_name	20 foot										40 foot									
		LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31	LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31
EXP	Pulp of wood and paper	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6
EXP	Recycled paper	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
EXP	Printing and Publishing	7.0	7.1	7.1	7.2	7.3	7.3	7.3	7.3	7.3	7.3	13.8	13.9	14.1	14.2	14.4	14.5	14.5	14.5	14.5	14.5
EXP	Petrol	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8
EXP	Diesel	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
EXP	Jet fuel	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
EXP	Other Petroleum Products	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1
EXP	Natural gas and Methane rich gas	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
EXP	Chemicals	17.7	17.9	18.1	18.3	18.4	18.6	18.6	18.6	18.6	18.6	17.7	17.9	18.0	18.2	18.4	18.6	18.6	18.6	18.6	18.6
EXP	Fertilizer	20.9	21.1	21.3	21.5	21.8	22.0	22.0	22.0	22.0	22.0	18.7	18.9	19.0	19.2	19.4	19.6	19.6	19.6	19.6	19.6
EXP	Pharmaceutical Products	12.5	12.6	12.7	12.8	13.0	13.1	13.1	13.1	13.1	13.1	16.1	16.2	16.4	16.5	16.7	16.9	16.9	16.9	16.9	16.9
EXP	Bricks	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	5.4	6.8	8.7	11.0	13.9	17.6	17.6	17.6	17.6	17.6
EXP	Cement	21.8	22.4	23.1	23.8	24.5	25.2	25.2	25.2	25.2	25.2	18.0	18.4	18.7	19.1	19.4	19.8	19.8	19.8	19.8	19.8
EXP	Iron & Steel	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
EXP	Ferrochrome	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7
EXP	Ferromanganese	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
EXP	Scrap metals	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3
EXP	Metal products, machinery and electronic equipment	13.9	14.0	14.0	14.1	14.1	14.2	14.2	14.2	14.2	14.2	12.8	12.9	12.9	13.0	13.0	13.1	13.1	13.1	13.1	13.1
EXP	Motor vehicles and trucks	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.2	7.2	7.2
EXP	Motor Vehicle Parts & Accessories	9.8	9.8	9.8	9.9	9.9	10.0	10.0	10.0	10.0	10.0	9.5	9.5	9.5	9.6	9.6	9.7	9.7	9.7	9.7	9.7
EXP	Transport Equipment	11.5	11.5	11.5	11.6	11.6	11.7	11.7	11.7	11.7	11.7	9.3	9.3	9.3	9.4	9.4	9.5	9.5	9.5	9.5	9.5
EXP	Other Manufacturing Industries	19.8	20.0	20.2	20.4	20.6	20.8	20.8	20.8	20.8	20.8	15.1	15.3	15.4	15.6	15.8	15.9	15.9	15.9	15.9	15.9
EXP	Non-Ferrous Metal Products	23.8	24.0	24.3	24.5	24.8	25.0	25.0	25.0	25.0	25.0	23.4	23.6	23.8	24.1	24.3	24.6	24.6	24.6	24.6	24.6
IMP	Barley	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	21.9	22.0	22.2	22.4	22.6	22.7	22.7	22.7	22.7	22.7
IMP	Grain Sorghum	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	15.7	16.5	17.5	18.5	19.5	20.6	20.6	20.6	20.6	20.6
IMP	Maize	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	13.7	14.8	16.0	17.3	18.7	20.3	20.3	20.3	20.3	20.3
IMP	Sunflower Seed	17.1	17.3	17.5	17.8	18.0	18.2	18.2	18.2	18.2	18.2	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7
IMP	Wheat	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	14.2	15.2	16.3	17.4	18.6	20.0	20.0	20.0	20.0	20.0
IMP	Soya beans	16.6	17.6	18.6	19.7	20.8	22.0	22.0	22.0	22.0	22.0	21.8	22.4	23.0	23.7	24.3	25.0	25.0	25.0	25.0	25.0

Direction	FDM_name	20 foot										40 foot									
		LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31	LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31
IMP	Rice	25.1	25.2	25.3	25.4	25.6	25.7	25.7	25.7	25.7	25.7	16.1	16.7	17.4	18.2	18.9	19.7	19.7	19.7	19.7	19.7
IMP	Vegetables	20.8	21.0	21.2	21.4	21.6	21.9	21.9	21.9	21.9	21.9	23.2	23.7	24.2	24.7	25.2	25.7	25.7	25.7	25.7	25.7
IMP	Potatoes	14.5	15.0	15.6	16.2	16.8	17.5	17.5	17.5	17.5	17.5	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9
IMP	Cassava	12.4	13.0	13.7	14.4	15.1	15.9	15.9	15.9	15.9	15.9	12.4	13.0	13.7	14.4	15.1	15.9	15.9	15.9	15.9	15.9
IMP	Sugar cane	12.4	13.0	13.7	14.4	15.1	15.9	15.9	15.9	15.9	15.9	12.4	13.0	13.7	14.4	15.1	15.9	15.9	15.9	15.9	15.9
IMP	Cotton	17.9	18.1	18.3	18.5	18.7	18.9	18.9	18.9	18.9	18.9	13.8	15.2	16.9	18.7	20.6	22.8	22.8	22.8	22.8	22.8
IMP	Grapes	7.7	8.1	8.4	8.8	9.2	9.7	9.7	9.7	9.7	9.7	10.8	12.0	13.4	14.9	16.6	18.4	18.4	18.4	18.4	18.4
IMP	Subtropical Fruit	12.3	13.1	14.0	15.0	16.0	17.1	17.1	17.1	17.1	17.1	12.6	13.8	15.1	16.6	18.2	20.0	20.0	20.0	20.0	20.0
IMP	Citrus	18.6	18.7	18.7	18.8	18.9	19.0	19.0	19.0	19.0	19.0	22.9	23.0	23.0	23.1	23.2	23.3	23.3	23.3	23.3	23.3
IMP	Deciduous Fruit	23.1	23.2	23.3	23.4	23.5	23.6	23.6	23.6	23.6	23.6	14.3	15.5	16.9	18.3	19.9	21.6	21.6	21.6	21.6	21.6
IMP	Milk (bulk)	15.5	16.2	16.9	17.7	18.5	19.3	19.3	19.3	19.3	19.3	15.5	16.2	16.9	17.7	18.5	19.3	19.3	19.3	19.3	19.3
IMP	Eggs (poultry)	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	7.9	8.0	8.1	8.2	8.3	8.4	8.4	8.4	8.4	8.4
IMP	Fish and seafood	18.0	18.1	18.1	18.2	18.3	18.3	18.3	18.3	18.3	18.3	23.4	23.5	23.6	23.6	23.7	23.8	23.8	23.8	23.8	23.8
IMP	Other Agriculture	15.9	16.0	16.1	16.1	16.2	16.3	16.3	16.3	16.3	16.3	18.5	18.6	18.7	18.8	18.8	18.9	18.9	18.9	18.9	18.9
IMP	Coal Mining Exports	19.7	19.8	19.9	19.9	20.0	20.0	20.0	20.0	20.0	20.0	19.7	20.6	21.5	22.5	23.5	24.5	24.5	24.5	24.5	24.5
IMP	Coal Mining Domestic	16.0	16.7	17.4	18.1	18.9	19.7	19.7	19.7	19.7	19.7	9.0	10.5	12.3	14.4	16.9	19.7	19.7	19.7	19.7	19.7
IMP	Coal Mining Powerstation	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7
IMP	Coal Mining Sasol	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7
IMP	Coal Mining Fly Ash	5.0	6.7	8.9	11.9	15.8	21.1	21.1	21.1	21.1	21.1	5.0	6.7	8.9	11.9	15.9	21.3	21.3	21.3	21.3	21.3
IMP	Crude oil	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
IMP	Iron Ore Exports	24.4	25.0	25.5	26.1	26.7	27.3	27.3	27.3	27.3	27.3	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4
IMP	Iron Ore Domestic	14.7	16.2	18.0	19.9	22.1	24.4	24.4	24.4	24.4	24.4	10.8	12.7	15.0	17.6	20.8	24.4	24.4	24.4	24.4	24.4
IMP	Precious metal ore	17.6	18.9	20.2	21.6	23.1	24.8	24.8	24.8	24.8	24.8	6.3	8.3	10.9	14.4	18.9	24.8	24.8	24.8	24.8	24.8
IMP	Precious metals and precious stones (Refined)	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2
IMP	Magnetite	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4
IMP	Chrome	19.0	20.1	21.3	22.6	24.0	25.4	25.4	25.4	25.4	25.4	22.2	22.7	23.2	23.8	24.3	24.9	24.9	24.9	24.9	24.9
IMP	Copper	20.6	21.3	22.1	22.8	23.6	24.5	24.5	24.5	24.5	24.5	18.9	20.2	21.5	23.0	24.5	26.1	26.1	26.1	26.1	26.1
IMP	Manganese Exports	24.8	25.2	25.7	26.1	26.6	27.1	27.1	27.1	27.1	27.1	24.8	25.2	25.7	26.1	26.6	27.1	27.1	27.1	27.1	27.1
IMP	Manganese Domestic	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
IMP	Titanium slag	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8

Direction	FDM_name	20 foot										40 foot									
		LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31	LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31
IMP	Rutile	23.5	23.9	24.4	24.9	25.4	25.9	25.9	25.9	25.9	25.9	23.5	23.9	24.4	24.9	25.4	25.9	25.9	25.9	25.9	25.9
IMP	Ilmenite (Titanium ore)	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8
IMP	Alumina	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
IMP	Gypsum	23.3	23.3	23.4	23.4	23.5	23.5	23.5	23.5	23.5	23.5	7.2	9.0	11.2	13.9	17.3	21.5	21.5	21.5	21.5	21.5
IMP	Zircon	5.2	7.0	9.4	12.7	17.1	23.1	23.1	23.1	23.1	23.1	4.9	6.7	9.0	12.2	16.5	22.3	22.3	22.3	22.3	22.3
IMP	Stone	21.8	22.2	22.6	23.1	23.6	24.1	24.1	24.1	24.1	24.1	18.6	19.2	19.8	20.4	21.1	21.7	21.7	21.7	21.7	21.7
IMP	Granite	22.3	23.1	23.9	24.7	25.6	26.5	26.5	26.5	26.5	26.5	4.7	6.1	7.9	10.2	13.2	17.0	17.0	17.0	17.0	17.0
IMP	Limestone	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3
IMP	Rock Phosphate	21.8	22.2	22.6	23.1	23.5	23.9	23.9	23.9	23.9	23.9	21.8	22.2	22.6	23.1	23.5	23.9	23.9	23.9	23.9	23.9
IMP	Sulphur	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
IMP	Fluorspar	24.2	24.3	24.5	24.7	24.8	25.0	25.0	25.0	25.0	25.0	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2
IMP	Salt	21.8	22.1	22.3	22.6	22.8	23.1	23.1	23.1	23.1	23.1	12.7	14.0	15.5	17.2	19.0	21.0	21.0	21.0	21.0	21.0
IMP	Other Non-Ferrous Metal Mining	25.0	25.2	25.5	25.7	26.0	26.3	26.3	26.3	26.3	26.3	24.6	24.8	25.1	25.3	25.6	25.8	25.8	25.8	25.8	25.8
IMP	Other Mining	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
IMP	Processed Foods	17.7	17.9	18.1	18.2	18.4	18.6	18.6	18.6	18.6	18.6	20.7	20.9	21.1	21.3	21.5	21.7	21.7	21.7	21.7	21.7
IMP	Slaughtered animal meat	25.3	25.6	25.8	26.1	26.3	26.6	26.6	26.6	26.6	26.6	23.0	23.2	23.5	23.7	23.9	24.1	24.1	24.1	24.1	24.1
IMP	Soya bean products	20.9	21.1	21.3	21.5	21.7	21.9	21.9	21.9	21.9	21.9	20.9	21.1	21.3	21.5	21.7	21.9	21.9	21.9	21.9	21.9
IMP	Animal feed	18.2	18.4	18.6	18.8	18.9	19.1	19.1	19.1	19.1	19.1	17.1	17.3	17.4	17.6	17.8	18.0	18.0	18.0	18.0	18.0
IMP	Beverages	16.4	16.6	16.8	16.9	17.1	17.3	17.3	17.3	17.3	17.3	21.2	21.4	21.6	21.8	22.0	22.2	22.2	22.2	22.2	22.2
IMP	Tobacco Products	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
IMP	Textile Products	7.2	7.3	7.3	7.4	7.5	7.5	7.5	7.5	7.5	7.5	11.9	12.0	12.1	12.2	12.4	12.5	12.5	12.5	12.5	12.5
IMP	Wood timber and products	16.8	17.0	17.2	17.3	17.5	17.7	17.7	17.7	17.7	17.7	20.0	20.2	20.4	20.6	20.8	21.0	21.0	21.0	21.0	21.0
IMP	Wood chips	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
IMP	Paper	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
IMP	Pulp of wood and paper	17.1	18.5	19.9	21.5	23.1	25.0	25.0	25.0	25.0	25.0	15.6	17.8	20.4	23.3	26.7	30.6	30.6	30.6	30.6	30.6
IMP	Recycled paper	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
IMP	Printing and Publishing	9.8	9.9	10.0	10.1	10.2	10.3	10.3	10.3	10.3	10.3	15.1	15.3	15.4	15.6	15.7	15.9	15.9	15.9	15.9	15.9
IMP	Petrol	19.5	20.6	21.7	22.8	24.1	25.4	25.4	25.4	25.4	25.4	20.0	20.1	20.3	20.5	20.6	20.8	20.8	20.8	20.8	20.8
IMP	Diesel	10.5	11.8	13.3	14.9	16.7	18.7	18.7	18.7	18.7	18.7	10.5	11.8	13.3	14.9	16.7	18.7	18.7	18.7	18.7	18.7
IMP	Jet fuel	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7

Direction	FDM_name	20 foot										40 foot									
		LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31	LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31
IMP	Other Petroleum Products	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
IMP	Natural gas and Methane rich gas	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
IMP	Chemicals	17.0	17.1	17.3	17.5	17.7	17.8	17.8	17.8	17.8	17.8	16.1	16.2	16.4	16.6	16.7	16.9	16.9	16.9	16.9	16.9
IMP	Fertilizer	19.4	19.6	19.8	20.0	20.2	20.4	20.4	20.4	20.4	20.4	18.4	18.6	18.8	19.0	19.1	19.3	19.3	19.3	19.3	19.3
IMP	Pharmaceutical Products	12.1	12.2	12.3	12.4	12.6	12.7	12.7	12.7	12.7	12.7	13.3	13.4	13.6	13.7	13.8	14.0	14.0	14.0	14.0	14.0
IMP	Bricks	22.4	22.6	22.9	23.2	23.5	23.8	23.8	23.8	23.8	23.8	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
IMP	Cement	25.2	25.7	26.3	26.8	27.4	27.9	27.9	27.9	27.9	27.9	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8
IMP	Iron & Steel	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
IMP	Ferrochrome	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
IMP	Ferromanganese	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
IMP	Scrap metals	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
IMP	Metal products, machinery and electronic equipment	10.7	10.8	10.8	10.8	10.9	10.9	10.9	10.9	10.9	10.9	9.9	9.9	9.9	10.0	10.0	10.1	10.1	10.1	10.1	10.1
IMP	Motor vehicles and trucks	8.3	8.3	8.3	8.4	8.4	8.4	8.4	8.4	8.4	8.4	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.0	8.0	8.0
IMP	Motor Vehicle Parts & Accessories	10.2	10.3	10.3	10.3	10.4	10.4	10.4	10.4	10.4	10.4	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.2	11.2	11.2
IMP	Transport Equipment	13.6	13.6	13.7	13.7	13.8	13.8	13.8	13.8	13.8	13.8	12.2	12.2	12.3	12.3	12.4	12.4	12.4	12.4	12.4	12.4
IMP	Other Manufacturing Industries	17.7	17.9	18.0	18.2	18.4	18.6	18.6	18.6	18.6	18.6	12.8	12.9	13.0	13.1	13.3	13.4	13.4	13.4	13.4	13.4
IMP	Non-Ferrous Metal Products	21.2	21.4	21.6	21.9	22.1	22.3	22.3	22.3	22.3	22.3	15.2	15.4	15.5	15.7	15.8	16.0	16.0	16.0	16.0	16.0

APPENDIX D - SURVEY QUESTIONNAIRES

The survey was made specific according to each of the various respondents' role in the supply chain. This led to slightly different surveys for each of the following groups:

- Associations and Organisations
- Freight Owners
- Logistics Service Providers
- Truck Companies
- Shipping Lines
- Port Terminal Operators
- Inland Depots and Warehouses

Due to the similarity, only the survey for one respondent will be provided in detail here, i.e. Logistics Service Providers

Survey Questionnaire: Logistics Service Providers

Question 1: Please describe the nature of your business:

- Agent
- Freight Forwarder
- Container Supplier
- Container Transport
- Container Storage
- Shipping Line
- Warehousing and Distribution
- Broker

Question 2: Please indicate a percentage split for the two types of container uses indicated below: [Please don't enter the % sign.]

- For import and export purpose
- For domestic transport

Question 3: From which country(s) do the majority of imported containers originate? (e.g. supplier origin such as China)

Question 4: Which country(s) are the majority of exported containers destined for?

Question 5: Have your source markets and destination markets changed substantially over the past 10 years?

- Yes
- No

Question 6: Do you foresee source markets and destinations (trade routes) changing substantially over the next ten years?

- Yes
- No

Question 7: What products do you mostly EXPORT via containers?

Question 8: What products do you mostly IMPORT via containers?

Question 9: What products do you mostly move domestically via containers (i.e. containers that don't cross a quay wall at a port)?

Question 10: How many containers did you IMPORT in 2013?

- Less than 100
- 100-250
- 250-500
- 500-1,000
- 1,000-2,500
- 2,500-5,000
- 5,000-10,000
- 1,0000-25,000
- 25,000-50,000
- More than 50,000
- My company does not import goods in containers

Question 11: How many containers did you EXPORT in 2013?

- Less than 100
- 100-250
- 250-500
- 500-1,000
- 1,000-2,500
- 2,500-5,000
- 5,000-10,000
- 1,0000-25,000
- 25,000-50,000
- More than 50,000
- My company does not import goods in containers

Question 12: How many containers did you move domestically in 2013 (i.e. did not cross a quay wall at a port)?

- Less than 100
- 100-250
- 250-500
- 500-1,000
- 1,000-2,500
- 2,500-5,000
- 5,000-10,000
- 1,0000-25,000
- 25,000-50,000
- More than 50,000
- My company does not import goods in containers

Question 13: What share of your international freight movements occur through these points of entry and exit for South Africa? (Note: Please do not enter the % sign.)

- Freight exported/imported by sea
- Freight exported/imported by air
- Freight exported/imported by road
- Freight exported/imported by train

Question 14: What factors drive transhipment of containers (the shipment of containers to an intermediate port before moving on to the final port destination)?

- Increasing fleet (vessel) size
- Required route not available
- Price
- Piracy

Question 15: What percentage of the imported, exported and domestic containers you handled in 2013 were the following types of containers? Note: Rows should add up to 100%, not columns.

- Import containers
- Export containers
- Domestic containers

Question 16: What drives the choice between using a 20 foot equivalent container (TEU) or a 40 foot equivalent container (FEU)? (Note: Can select more than one per row.)

Answer Options	**Price**	**Availability of container stock**	**Availability of slots on vessels**	**Availability of loading bays/stacking space at port**	**Handling capability at port**	**Shipping route**	**Parcel size**	**Nature of the commodity**
Import containers								
Export containers								
Domestic containers								

Question 17: What drives the use of irregular sized containers such as high cube/open top/larger than FEU containers? (Note: Can select more than one per row.)

Answer Options	**N/A I do not use irregular sized containers**	**Price**	**Availability of the containers**	**Availability of slots on vessels**	**Availability of loading bays/stacking space at port**	**Handling capability at port**	**Shipping route**	**Parcel size**	**Nature of the commodity**
Import containers									
Export containers									
Domestic containers									

Question 18: What drives the use of tanktainers (tanks held within a container frame only) or flexi-tanks (fabric bags filled with liquid and transported inside containers) as opposed to transporting liquid as bulk?

(Note: Can select more than one per row.)

Answer Options	**N/A I do not use flexitanks or tanktainers**	**Price**	**Availability of the containers**	**Availability of slots on vessels**	**Availability of loading bays/stacking space at port**	**Handling capability at port**	**Shipping route**	**Parcel size**	**Due to Hazardous Materials**	**Due to Food Grade Liquids**
Import containers										
Export containers										
Domestic containers										

Question 19: Has the use of the following container types increased or decreased over the LAST 10 years? Please answer for each type of container.

Question 20: Do you foresee the use of the following container types increasing, decreasing or staying the same over the NEXT 10 years? Please answer for each type of container.

TEU					
Answer Options	**Increased**	**Decreased**	**Stayed the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

FEU					
Answer Options	**Increased**	**Decreased**	**Stayed the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

High cube					
Answer Options	**Increased**	**Decreased**	**Stayed the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Open top/side					
Answer Options	**Increased**	**Decreased**	**Stayed the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Irregular sized					
Answer Options	**Increased**	**Decreased**	**Stayed the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Tanktainer					
Answer Options	**Increased**	**Decreased**	**Stayed the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					
Flexitank					
Answer Options	**Increased**	**Decreased**	**Stayed the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Reefer					
Answer Options	**Increased**	**Decreased**	**Stayed the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Question 21: Do you foresee, or have your experienced goods being transported in an alternative unit to containers, i.e. a new type of unitised storage?

TEU					
Answer Options	**Increase**	**Decrease**	**Stay the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

FEU					
Answer Options	**Increase**	**Decrease**	**Stay the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

High cube					
Answer Options	**Increase**	**Decrease**	**Stay the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					
Open top/side					
Answer Options	**Increase**	**Decrease**	**Stay the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Irregular sized					
Answer Options	**Increase**	**Decrease**	**Stay the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Tanktainer					
Answer Options	**Increase**	**Decrease**	**Stay the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					
Flexitank					
Answer Options	**Increase**	**Decrease**	**Stay the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Reefer					
Answer Options	**Increase**	**Decrease**	**Stay the same**	**N/A**	**Response Count**
Imports					
Exports					
Domestic					

Question 22: Have you experienced a drive towards greater volumes packed into each container?

Answer Options	**Yes**	**No**
International containers		
Domestic containers		
If yes, what is this new trend?		

Question 23: If yes, what motivates this drive?

- Cost/economies of scale
- Improvements in distribution chains
- Changes in manufacturing processes
- Increased market share

Question 24 If yes, how do you fit more into a single container and how has this impacted on your business?

Question 25: Where do you unpack/pack your containers? Note: Rows should add up to 100%

Within the port of entry/exit												
Answer Options	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**	**Response Count**
Imports												
Exports												
Domestic												

Near to the port of entry/exit at a warehouse/hub												
Answer Options	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**	**Response Count**
Imports												
Exports												
Domestic												

At a central distribution facility placed closer to the consumer market												
Answer Options	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**	**Response Count**
Imports												
Exports												
Domestic												

Near to the site the goods are manufactured at a warehouse/hub												
Answer Options	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**	**Response Count**
Imports												
Exports												
Domestic												

On-site (your own factory/premises)												
Answer Options	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**	**Response Count**
Imports												
Exports												
Domestic												

Other												
Answer Options	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**	**Response Count**
Imports												
Exports												
Domestic												

Question 26: What drives when and where you unpack your containers? Note:

You can select more than one answer

Answer Options	**Redistribution of parcel to multiple receivers**	**Weight or Size of container not suitable for specific mode (i.e. too heavy or too long)**	**Nature of the commodity (i.e. time or environment sensitive)**	**We do not have a say in this as the logistics service provider manages this process**	**Other**
Imports					
Exports					
Domestic					

Question 27: Where do you source your Empty containers from? (Note: You can select more than one option.)

- From full containers that are delivered to us (we do not own these containers but use them to export freight)
- Buy/rent from a container manufacturer/storage facility
- Rent from a shipping line's logistic unit
- On-site storage (own our own containers)
- We do not have a say in this as the logistics service provider manages this process

Question 28: Do you most often return containers to where they were sourced (as indicated above)?

- Yes
- No

Question 29: What percentages of your containers are transported via road, rail, ship and air within the local hinterland? Note: As some containers will use two or more modes percentages are not required to add up to 100%.

- Road (truck)
- Rail
- Coastwise Ship (e.g. shipment between Cape Town and Durban)
- Local Air

Question 30: Please rank what has driven your modal choice (as indicated above) until now? (Note: 1 is most important and 7 is not important.)

Answer Options	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Availability of infrastructure on required routes							
Price							
Time							
Reliability							
Accessibility							
Security/damage to freight							
Ease of use							

Question 31: Do you have any plans to change your predominant modal choice in the future (e.g. road to rail)?

- Yes, moving more to road ☐
- Yes, moving more to rail ☐
- Yes, moving more to coastwise shipment ☐
- Yes, moving more to air ☐
- No ☐

Question Q32 What would encourage you to use rail more often for the movement of containers around Southern Africa? Note: You can select more than 1 option

- More rail routes and branch lines ☐
- Modal interfaces that allow for road and rail ☐
- Better rail service reliability ☐
- Container hubs/dry ports connected to rail routes ☐
- Lower price ☐

Question 33: As a percentage, how much less, would rail transport cost need to be in comparison to road, in order for you to choose rail transport over road transport?

- 2% less than road transport ☐
- 5% less than road transport ☐
- 10% less than road transport ☐
- 20% less than road transport ☐
- 25% less than road transport ☐
- 50% or more less than road transport ☐
- I will not use rail regardless of the price difference ☐

Question 34: Final Container Question: What factors do you think will most impact the rate of containerisation (movement of freight into containers) in the near future for the following commodities? Please consider only those commodity groups that your firm transports at present, e.g. Citrus: Destination port regulations require all fruit to be in reefer for health reasons leading to increased containerisation of citrus fruit.

- Ferrochrome
- Ferromanganese
- Iron and Steel basic industries
- Non-metallic mineral products e.g. glass, ceramic, clay, lime, concrete, stone etc.
- Wood and wood products e.g. wood, cork, straw and plaiting materials
- Paper and paper products e.g. pulp, paperboard, stationary
- Industrial chemicals e.g. industrial gasses, basic organic chemicals, dyestuff, tanning
- Other chemicals e.g. pigments, thinners etc. used in painting industry, explosives, gelatin, peptones, oils, ink, plastics, photo-chemicals etc.
- Fertilizer and Pesticides e.g. urea, insecticides, ammonia etc.
- Food and food processing e.g. meat, fish, fruit, veg, oils, fats, grain, bakery, sugar, coffee, condiments etc.
- Citrus
- Deciduous fruit
- Vegetables
- Machinery and equipment e.g. turbines, engines,pumps, taps, bearings, ovens, special purpose machinery mining etc.
- Transport Equipment e.g. bodies for motor vehicles, building and repair of ships and boats, railway, aircraft, motorcycles etc.
- Motor vehicle parts and accessories
- Other manufacturing industries e.g. jewelry, musical instruments, toys, sports goods, signage, recycling etc.

APPENDIX E – FOCUS GROUP AGENDA AND DISCUSSION POINTS

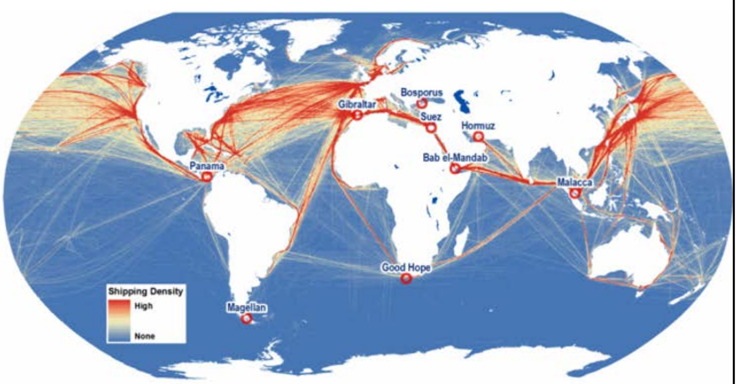
The focus group was in the format of a short introductory slideshow to provide background. This was followed by a number of slides that asked questions that focus group attendees were encouraged to discuss in the bigger group or contribute to with notes, or voting where appropriate. The slides used for the discussion aspects are provided below in picture format.

The question for Today's Discussion

- Quay wall
  - Including: Full Containers, Empties and Transhipments
  - Quay wall decisions:
    - Which Port?
    - Weight per TEU
    - Physical type of container
- Flow into hinterland
  - Decisions you make to route your freight?
    - Packing/Unpacking containers
    - Modal choice
- Domestic Containers
  - Similar as above or not?

Currently modelled factors

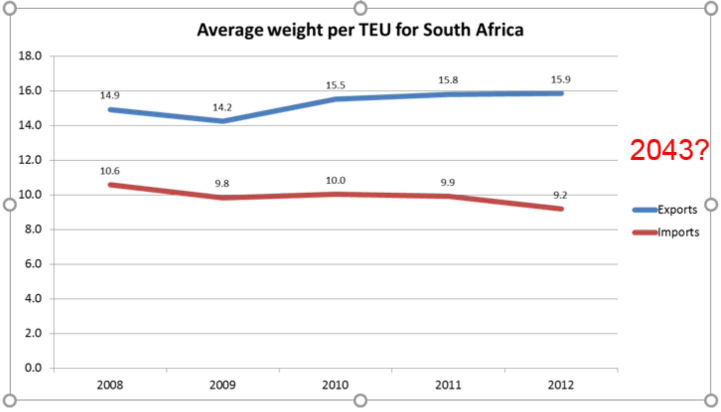
- Which Port?
  - Nature of the commodity
  - Final destination of freight
  - Facility's distance from ports
  - Shipping line calling at ports
  - Linkages to dry ports



Open Discussion

Currently modelled factors

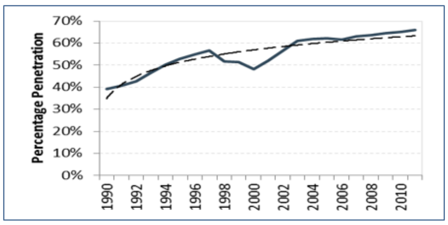
- Weight per TEU
  - Reasons for past trends
  - Future trends
  - Impact on modes of transport



Open Discussion

Currently modelled factors

- Pick up %
  - Reasons for past trends
  - Future trends
  - Ceiling per commodity
  - Consistency vs variability?



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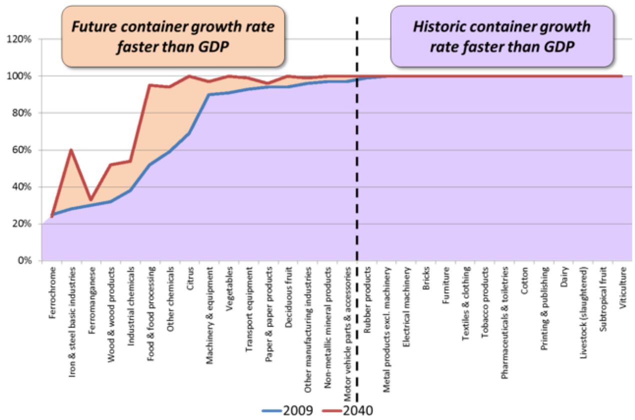
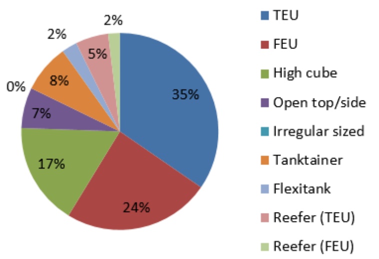


Open Discussion

To Be modelled Factors

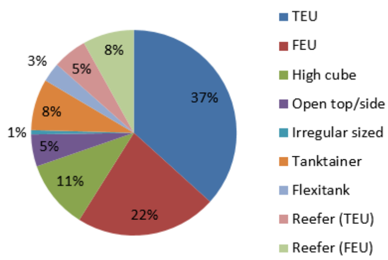
- Physical Typology
  - Sizes
    - 20 foot
    - 40 foot
    - 20 foot reefer
    - 40 foot reefer
    - High cube,
    - Tanktainer,
    - Open top/side, Irregular size

Imports



Source: Project Survey

Exports

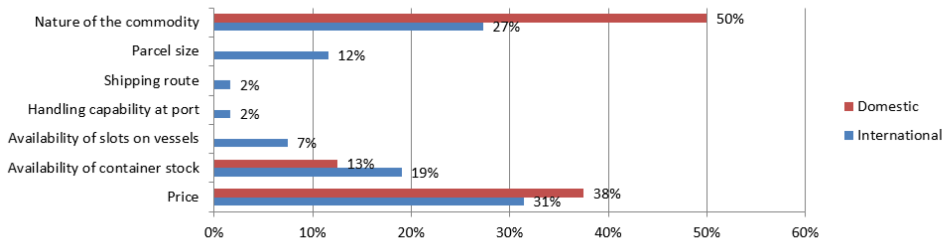


Source: Project Survey

To Be modelled Factors

- Physical Typology
  - Decision factors:
    - Nature of the commodity
    - Parcel size
    - Shipping Route
    - Handling capability at destination/port
    - Availability of slots on vessels
    - Availability of empty containers
    - Price

TEU vs. FEU

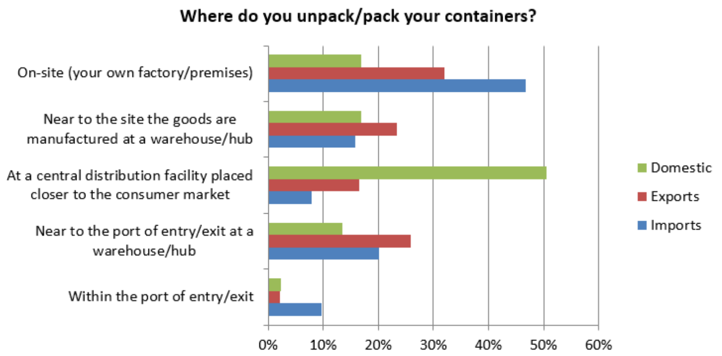


Source: Project Survey

Open Discussion

To Be modelled Factors

- Unpack/pack (hinterland)
  - Location:
    - At or near the Port
    - Distribution Centre
    - Warehouse
    - Factory

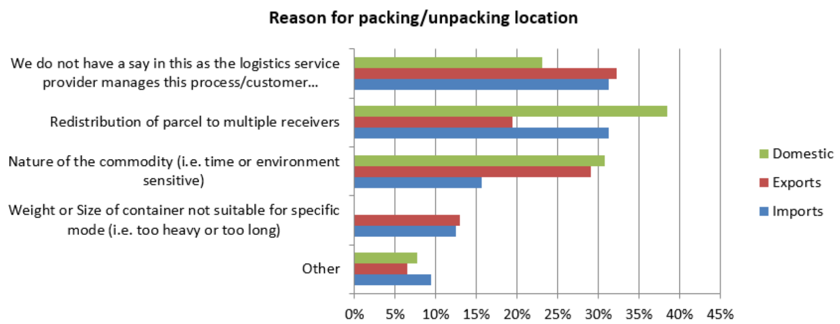


Source: Project Survey

Open Discussion

To Be modelled Factors

- Unpack/pack (hinterland)
  - Why at this location:
    - Nature of the commodity
    - Weight or Size of the container not suitable for mode
    - Redistribution to multiple receivers
    - Other

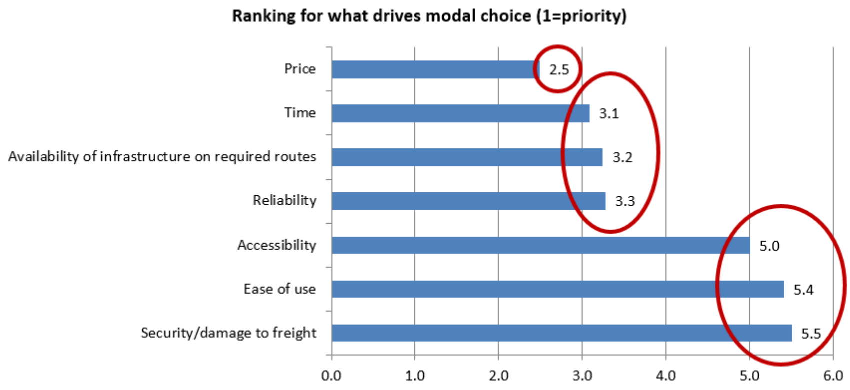


Source: Project Survey

Open Discussion

To Be modelled Factors

- Modal choice
  - Drivers of modal choice:

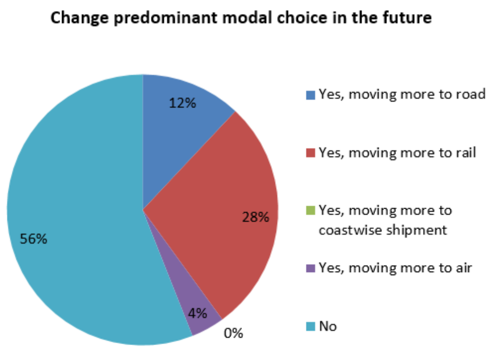


Source: Project Survey

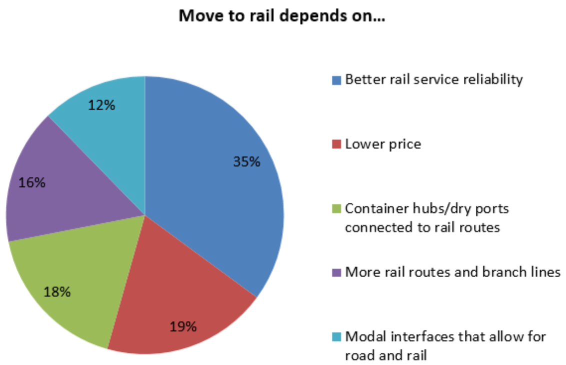
Comments

To Be modelled Factors

- Modal choice
  - What would facilitate a modal shift towards rail



Source: Project Survey

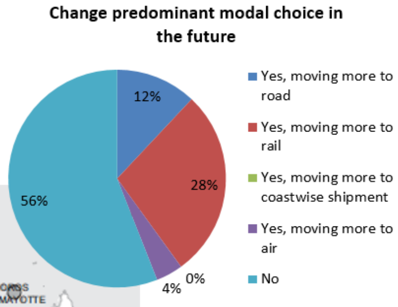


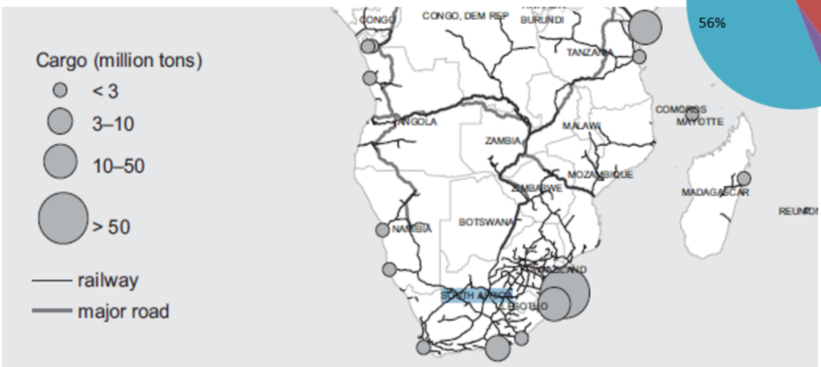
Source: Project Survey

Comment Cards

Other Themes

- Coastal shipment
  - Shipping line routes
  - Cost of port handling
  - Port and back of port congestion

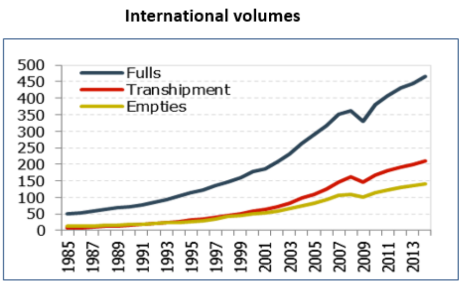




Open Discussion

Other Themes

- Empties
  - Imbalance of trade (Seasonality, etc.)
  - Source of Empties
    - Rent from shipping lines
    - Unpacking full
    - Buy/rent from container manufacturing/storage facility



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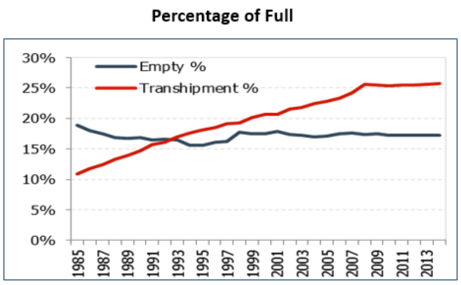
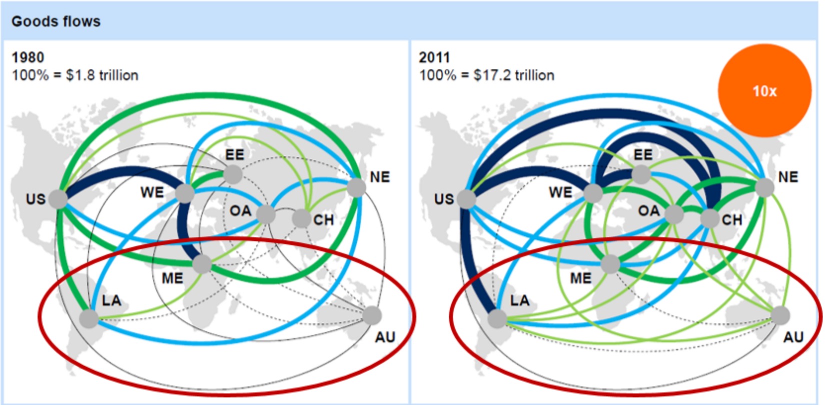


Source: Drewry

Open Discussion

Other Themes

- Transhipment
  - Increased freight movements south of the equator
  - Required route not available
  - Increasing vessel size
  - Price
  - Piracy



Source: McKinsey Global Institute: Global flows in a digital age

Open Discussion

APPENDIX F – PHYSICAL TYPE FAMILIES

Transnet port infrastructure planners indicated during discussions that they would prefer to plan for a breakdown of container types by using the following physical types:

- Normal Twenty Foot Unit (NTFU)
- Normal Forty Foot Unit (NFFU)
- Normal High cube Forty Foot Unit (HFFU)
- Open Top Twenty Foot Unit (OTFU)
- Irregular sized Twenty Foot Unit (ITFU)
- Tanktainer (twenty foot) (TANK)
- Flexitank (twenty foot) (FANK)
- Reefer Twenty Foot Unit (RTFU)
- Reefer Forty Foot Unit (RFFU)

In order to incorporate this into the proposed content-based models a percentage split per container physical type per commodity needed to be made over the complete forecast horizon. There is insufficient input data to define this.

The concept of physical type families provides for a lower modelling complexity than trying to be specific for all 83 commodities over all the forecast years. The six physical type families have been defined as:

- General Containerised (GC);
- Partly Refrigerated (PR);
- Refrigerated Only (RO);
- Refrigerated liquids (RL);
- Liquids only (LO); and
- Liquids mixed (LM).

Sufficient input data is available to define modelling values for these six physical type families. These can then be linked to the commodity groups and used to model container physical types as required by port infrastructure planners, as shown in the diagram below repeated from Figure 6.9:

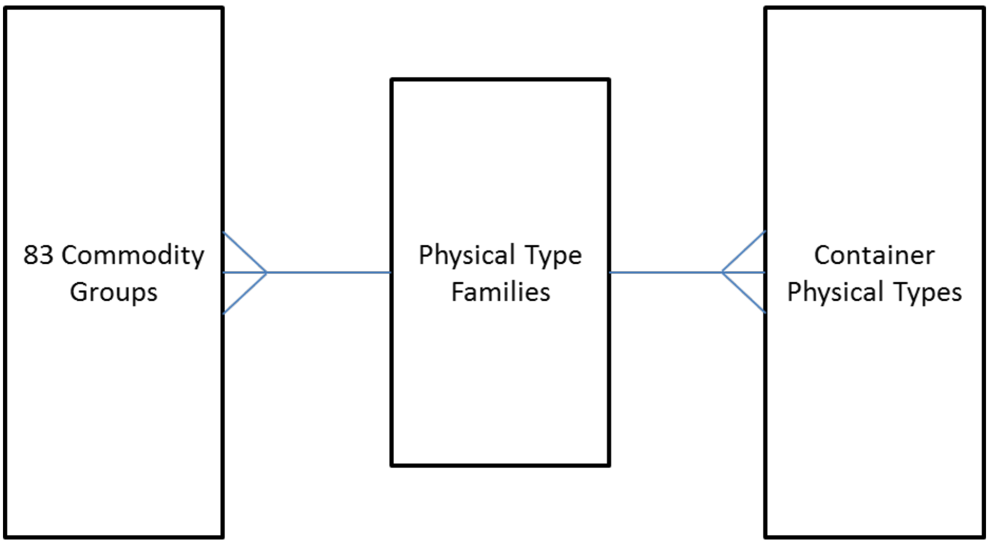


Figure F.1: Relationship diagram between commodities, physical types and physical type families

The table on the next page provides the complete list of physical type families and their link to container physical types. A short explanation of each field is necessary:

- **PhysTypeFamCode**: Short code used in definition and modelling.
- **PhysTypeFamName**: Descriptive name used in discussions.
- **83FDM_cont_name**: The containerised commodities are transferred into these container family groupings in the FDM for surface freight modelling.
- **IMP/EXP**: Directional differences might exist between commodities and physical type families
- **LK_00**: Base year for input values
- **LK_01**: Current model year
- **LK_02**: Forecast year 1
- **LK_03**: Forecast year 2
- **LK_04**: Forecast year 3
- **LK_05**: Forecast year 4
- **LK_06**: Forecast year 5
- **LK_11**: Forecast year 10
- **LK_16**: Forecast year 15
- **LK_31**: Forecast year 30
- **5YrCAGR**: 5-year compound annual growth rate used to change percentages over the forecast horizon
- **30YrCAGR**: 5-year compound annual growth rate used to change percentages over the forecast horizon

PhysType FamCode	PhysTypeFamName	FDM_cont_name	IMP/EXP	LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31	5YrCAGR	30YrCAGR
GC	General containerised	NTFU	IMP	32%	31%	29%	28%	27%	26%	25%	21%	18%	12%	-4.0%	-3.1%
GC	General containerised	NFFU	IMP	59%	60%	60%	61%	62%	62%	63%	64%	65%	69%	1.1%	0.4%
GC	General containerised	HFFU	IMP	6.5%	7%	7%	8%	8%	9%	9%	10%	11%	15%	5.6%	2.3%
GC	General containerised	OTFU	IMP	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%	0.0%	0.2%
GC	General containerised	ITFU	IMP	0.5%	1%	1%	1%	1%	1%	0.50%	1%	1%	1%	0.0%	0.3%
GC	General containerised	TANK	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
GC	General containerised	FANK	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
GC	General containerised	RTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
GC	General containerised	RFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
PR	Partly refrigerated	NTFU	IMP	23%	22%	21%	20%	20%	19%	18%	16%	14%	9%	-4.0%	-2.9%
PR	Partly refrigerated	NFFU	IMP	42%	42%	43%	43%	44%	44%	45%	46%	47%	50%	1.2%	0.5%
PR	Partly refrigerated	HFFU	IMP	5.0%	5%	6%	6%	6%	7%	7%	8%	8%	11%	5.8%	2.1%
PR	Partly refrigerated	OTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
PR	Partly refrigerated	ITFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
PR	Partly refrigerated	TANK	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
PR	Partly refrigerated	FANK	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
PR	Partly refrigerated	RTFU	IMP	14%	13%	13%	12%	12%	11%	11%	9%	8%	5%	-3.9%	-3.3%
PR	Partly refrigerated	RFFU	IMP	16%	16%	17%	17%	18%	18%	19%	20%	21%	25%	2.9%	1.2%
RO	Refrigerated only	NTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RO	Refrigerated only	NFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RO	Refrigerated only	HFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RO	Refrigerated only	OTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RO	Refrigerated only	ITFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RO	Refrigerated only	TANK	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RO	Refrigerated only	FANK	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RO	Refrigerated only	RTFU	IMP	45%	43%	41%	40%	38%	36%	35%	29%	25%	15%	-4.1%	-3.5%
RO	Refrigerated only	RFFU	IMP	55%	57%	58%	60%	61%	63%	65%	69%	73%	85%	2.8%	1.2%
RL	Refrigerated liquids	NTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RL	Refrigerated liquids	NFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RL	Refrigerated liquids	HFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%

PhysType FamCode	PhysTypeFamName	FDM_cont_name	IMP/EXP	LK_00	LK_01	LK_02	LK_03	LK_04	LK_05	LK_06	LK_11	LK_16	LK_31	5YrCAGR	30YrCAGR
RL	Refrigerated liquids	OTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RL	Refrigerated liquids	ITFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
RL	Refrigerated liquids	TANK	IMP	12%	12%	12%	11%	11%	11%	11%	11%	11%	10%	-1.4%	-0.4%
RL	Refrigerated liquids	FANK	IMP	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	-6.5%	-0.3%
RL	Refrigerated liquids	RTFU	IMP	38%	37%	35%	34%	32%	31%	30%	25%	21%	13%	-3.9%	-3.4%
RL	Refrigerated liquids	RFFU	IMP	47%	49%	50%	52%	53%	55%	57%	60%	64%	75%	3.3%	1.2%
LO	Liquids only	NTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LO	Liquids only	NFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LO	Liquids only	HFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LO	Liquids only	OTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LO	Liquids only	ITFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LO	Liquids only	TANK	IMP	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	0.0%	0.0%
LO	Liquids only	FANK	IMP	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	0.0%	0.0%
LO	Liquids only	RTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LO	Liquids only	RFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LM	Liquids mixed	NTFU	IMP	26%	25%	24%	23%	22%	21%	20%	18%	16%	11%	-4.3%	-2.5%
LM	Liquids mixed	NFFU	IMP	48%	49%	49%	50%	51%	51%	52%	53%	54%	57%	1.3%	0.4%
LM	Liquids mixed	HFFU	IMP	6.0%	6%	7%	7%	7%	8%	8%	9%	9%	12%	4.9%	1.8%
LM	Liquids mixed	OTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LM	Liquids mixed	ITFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LM	Liquids mixed	TANK	IMP	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%	0.0%	0.0%
LM	Liquids mixed	FANK	IMP	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	0.0%	0.0%
LM	Liquids mixed	RTFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
LM	Liquids mixed	RFFU	IMP	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.0%	0.0%
GC	General containerised	NTFU	EXP	50%	48%	46%	45%	43%	42%	40%	34%	28%	17%	-3.7%	-3.5%
GC	General containerised	NFFU	EXP	37%	38%	39%	40%	41%	42%	43%	46%	49%	59%	2.5%	1.4%
GC	General containerised	HFFU	EXP	8%	9%	9%	10%	10%	11%	12%	13%	14%	18%	7.0%	1.9%

APPENDIX G – MODELLING ELEMENTS: MARINE COASTAL CONTAINERS

Marine coastal was excluded from the scope of this dissertation early on due to its insignificant volumes. With the information available, a modelling framework could be done for use if policy or business decisions should change that make this a more viable and thus more significant alternative. The model discussion similar to the models for the other three typologies in Chapter 8, follows.

Marine coastal is an alternative transport mode to road or rail surface transport. As shown from the industry datasets, this contributes between 1% and 1.5% of marine deep-sea full containers to total port volumes. This mode would only be used if it makes business sense for freight owners in terms of their supply chain strategy. As indicated with the focus groups and survey feedback in the previous chapter, the reliability, cost and delivery cycle times would dictate if this alternative mode would be used over road or rail.

The modelling elements derived for marine coastal full containers from Chapters 5 and 6 are shown in Figure G.1 and are discussed in detail below. This excludes the coastal relocation of empty containers that are included in the empty container model segment.

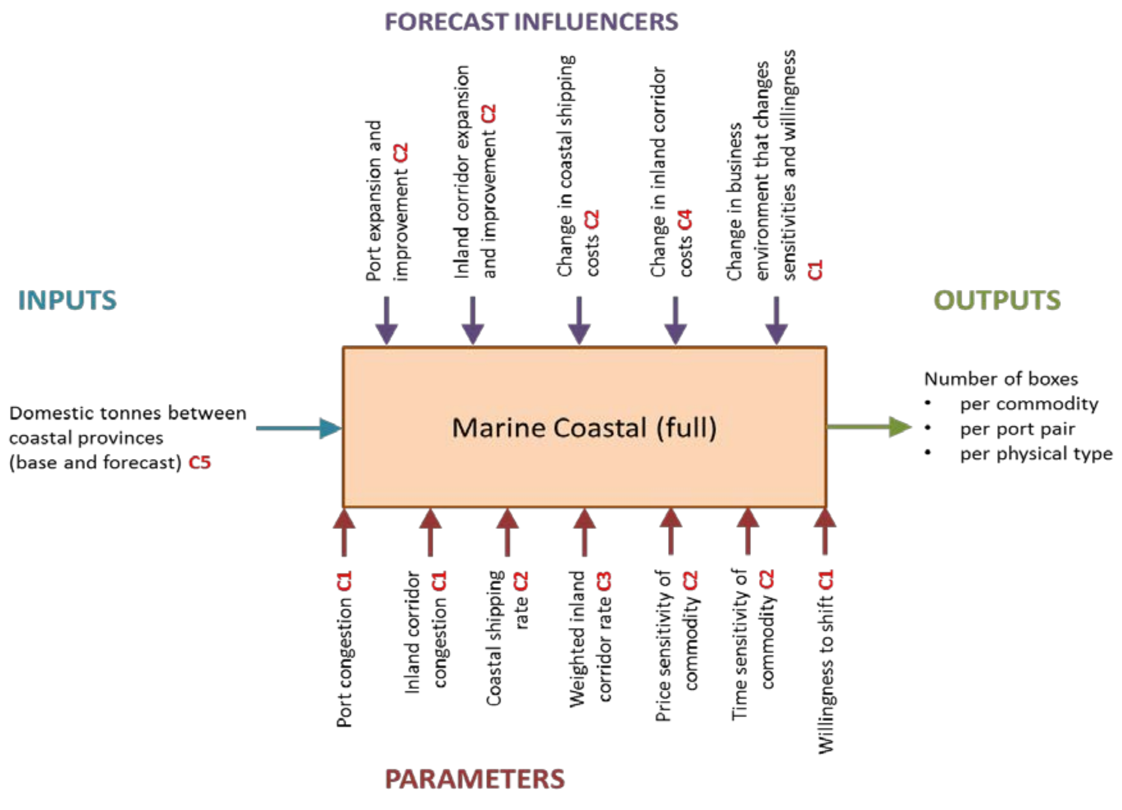


Figure G.1: Modelling elements for the Marine coastal full container segment

The input data for marine coastal would be domestic tonnes between coastal provinces. For example transporting sugar from Durban to Cape Town might be feasible if the freight owners find the terms favourable. The port infrastructure is available at both ports for bulk and container shipments. The FDM used by Transnet has detail on freight movements between 356 modelling districts in South Africa with detailed tonnes per origin-destination pair per commodity. It can be safely assumed that origin-destination pairs in coastal provinces relatively close to both ports (with active container terminals) would be an option for this mode, as long as the distances to the port on both ends of the coastal shipment are not considerably long.

The container model segment for this typology follows a two-phased approach:

- The first phase identifies domestic freight that could utilise the coastal marine mode. District pairs have been analysed to determine which would be potential market share for a coastal transport mode. The parameters below are then used to determine which portion of this subset would utilise the coastal shipment route and has an output of coastal tonnes per commodity.
- The second phase utilises the output tonnes per commodity from the first phase and then duplicates the marine deep-sea typology process to containerise these tonnes for each commodity according to percentage containerisation, weight per TEU and container type allocation. The marine deep-sea parameter input values per commodity are used for coastal as well.

The parameters considered for establishing the volume of freight to be using the coastal option were mostly derived from literature in Chapters 2 and 3 with inputs from especially the focus group participants described in Chapter 6. The parameters are the following:

- Relative congestion: This is a function of port congestion for both ports and inland corridor congestion between the origin and destination. Articles from Chapter 2 indicated port efficiency to be an important port competitive value. Congestion has a time impact, and one would expect commodities that are more time sensitive to stay away from long time delays due to congestion. A relative congestion factor has been derived for all potential origin-destination pairs based on current road/rail and port conditions between them. The parameter was defined but more research would be needed to assign accurate values to the parameters for current and future forecast years.
- Price comparison: A coastal shipping rate needs to be compared to weighted inland corridor rates (road and rail) in order to determine the likelihood of a shift with price-sensitive commodities. One aspect contributing to the price comparison is the difference in distance. Cost comparison was often used in mode and port competitiveness modelling in research discussed in Chapter 2. A long road/rail transport leg to and from the port would make the price of coastal shipment not comparable to the road/rail mode alternatives.
- Price sensitivity of the commodity: Safety stock is a function of lead time. Currently the time it takes for coastal shipping vs road or rail is much longer. High-value commodities using coastal shipment under current lead times would cause high inventory levels and working capital pressure. Thus higher-value items would not lean towards coastal shipment. The shipping line sample did provide some inputs into the types of commodities that might utilise coastal shipments if origin and destination locations relative to ports permit this.
- Time sensitivity of the commodity: Perishable items would not benefit from current long port delays with coastal shipments. However as was seen in the shipping line sample data, low-value, time insensitive items like sugar, mined salt, recycled paper, or some chemicals could benefit from cheaper coastal rates.
- Willingness to shift: Some survey and focus group participants commented that they would not consider shifting to a coastal transport mode even if it was for free. Their arguments were related to long time delays and serious reliability issues. Although these performances could be changed through dedicated investments and efficient processes, their perception of this mode would be difficult to change in the short to medium term.

The process followed to determine tonnes using the coastal route were to first calculate a time factor based on the relative congestion and the commodity's time sensitivity. This would generate a value between 0 and 1, where 0 means it would be not time sensitive, and 1 very sensitive. Similarly a price factor was calculated considering the relative price and the price sensitivity. This would also generate a value between 0 and 1, where 0 means it would be not price sensitive, and 1 very price sensitive. The shift probability was then determined by the function:

Shift probability = 1 – Time factor – price factor (per commodity, per port pair)

The shift probability could only be between 1 and 0, not smaller than 0. In this way if either the time factor or the price factor (or both) were high the commodity would not shift to coastal shipment. The shift attenuation was a further factor listed above that indicated the willingness of freight owners (value between 0 and 1) in specific commodity groups to shift to coastal transport. The final coastal tonnes would be determined by multiplying the available tonnes with both the shift probability and the shift attenuation, providing a market share for coastal transport.

Various aspects were discussed in the focus groups and comments were made in the survey feedback about items that influences the coastal decision and would provide changes to this in future:

- Port expansion and efficiency improvement: One aspect that came up various times in the focus groups was the availability of port capacity which operated efficiently. Coastal shipment was deemed only an alternative mode option if both ports have the infrastructure, capacity and can operate reliably.
- Inland corridor expansion and improvement: Contrary to the port example above, if inland road and rail capacity and efficiencies deteriorate, and no new capacity is developed as the economy grows, issues might arise that improve the relative position for the coastal mode.
- Change in coastal shipping costs: At this stage freight owners did not always experience the coastal option as a cheaper option when considering the Total Cost of Ownership approach, mainly due to the unreliability of port services. If Transnet in cooperation with coastal shipping companies would target this mode and provide better rates, increased reliability and capacity, this could be a viable option for more freight owners.
- Change in inland corridor costs: The excessive crude oil prices recorded over a few years led to many investigations into alternative modes to the very fuel-dependent road cost. If future repetitions of this high crude price occur, then inland corridors might have less-favourable pricing.
- Change in business environment that changes sensitivities and willingness: Certain non-perishable, low-value commodities might not be that vulnerable to the coastal shipping lead time and reliability issues. Some of these are already utilising coastal shipment as an option. A change in business environment for other commodities might increase the likeliness and willingness to transfer to coastal shipment.

The output that the marine coastal model generates is:

- the number of containers:
    - per commodity,
    - per origin and destination district and port pair,
    - per physical container type.

The above method is applied to all the forecast years available to port planners. The allocation of district-to-district combinations that are suitable for coastal shipments needs to be revised on a frequent basis to ensure that viable freight is included as a potential market share for the coastal port segment of the container model.

The author has confidence that the proposed method and parameters for the coastal container model segment could provide accurate inputs to the larger quay wall container model. The confidence levels of the modelling input values for the coastal modelling segment are shown in Table G.1.

Table G.1: Confidence level: Modelling elements for marine coastal full containers

Functional Typology	Modelling element	Modelling aspect	C1	C2	C3	C4	C5
Marine Coastal Full	Inputs	Domestic tonnes between coastal provinces					X
	Parameter values used	Port congestion	X				
		Inland corridor congestion	X				
		Coastal shipping rate		X			
		Weighted inland corridor rate			X		
		Price sensitivity of commodity		X			
		Time sensitivity of commodity		X			
		Willingness to shift	X				
	Forecast Influencers	Port expansion and improvement		X			
		Inland corridor expansion and improvement		X			
		Change in coastal shipping costs		X			
		Change in inland corridor costs				X	
		Change in business environment that changes sensitivities and willingness	X				
	Outputs: Base Year	Number of containers: per commodity per port pair per physical type			X		
	Outputs: Forecast years	Number of containers: per commodity per port pair per physical type			X		

Many of the input parameters in this table are derived from perceived influences picked up during the literature review in Chapters 2 and 3 and the data analysed in Chapters 5 and 6**Error! Reference source not found.**. These aspects were included in the focus group discussions and were confirmed by participants as aspects that should be included in the modelling. Despite this very little hard evidence was available to populate the input parameters with in-depth researched values.

High-level relative congestion and transport rates could be determined from available datasets from other non-related research projects, but confidence levels of C1 and C2 were assigned to these respectively. The research team understand the domestic transport cost factors for South Africa quite well, thus the current inland corridor rate was lifted to level C3 and the related influencing factors was given a C4. Price and time sensitivity of commodities could be estimated by informal discussions with industry exports for most of the commodity groups, thus a C2 confidence was in order. The shipping line sample data was used to simulate the current freight volumes and derive values for shift attenuation, and thus it was used more as a balancing factor to almost limit the available volumes to what is currently moved. It acts almost like a damping factor, thus the confidence level of C1. More research work is required to determine a method to provide current and future values for this.

Further research work should be done to obtain unique parameter values for the coastal segment of the model. At this stage the parameter values implemented might be very subjective due to the lack of detailed input information. Due to the current low market share of between 1% and 1.5 % of full containers, no large-scale time investment was justifiable to obtain more accurate input parameters values as part of this dissertation. Currently the volumes are small and the available datasets provide little input for detailed analysis. This leaves the researcher with a reliance on data from the marine deep-sea model segment regarding the percentage containerised, weight per container and type of container preferred. Long-term dependence on marine deep-sea parameter values should be reduced, if it is not shown to be similar in nature. Further research is advised to obtain its own unique detailed parameter values.